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# Results of Bioventing System Monitoring

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**PARSONS ENGINEERING SCIENCE, INC.**

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October 1, 1997

Major Ed Marchand  
AFCEE/ERT  
3207 North Road, Bldg. 532  
Brooks AFB, Texas 78235-5363



**Subject: Results of Bioventing System Monitoring at Spill Site No. 1, Building 457 Area, and UST 702, Eaker AFB, Arkansas (Contract F41624-92-D-8036, Order 17)**

Dear Major Marchand:

Parsons Engineering Science, Inc. (Parsons ES) is pleased to submit the results of the extended bioventing testing and additional site investigative field work at Spill Site No. 1, Building 457 Area, and UST 702, Eaker Air Force Base (AFB), Arkansas. The testing and field work were performed during the week of June 15, 1997, after 13 months of continuous pilot-scale bioventing system operation (i.e., at the 13-month project milestone) and one month of system shutdown. Four primary tasks were accomplished at each site during this field event: 1) additional soil borings were installed to better define the full-areal extent (FAE) of petroleum contamination (four borings at Spill Site No. 1 were used for installation of soil vapor monitoring points), 2) groundwater sampling and analysis were performed to qualitatively evaluate the potential for natural chemical attenuation to remediate petroleum contaminants dissolved in groundwater, 3) an *in situ* respiration test was conducted to determine the current rates of oxygen utilization by fuel-degrading soil microbes, and 4) field and laboratory soil gas samples were collected from vapor monitoring points at each site 1 month after blower shutdown, and analyzed to determine the changes in oxygen, carbon dioxide, total volatile hydrocarbons (TVH) and benzene, toluene, ethylbenzene, and total xylenes (BTEX) concentrations after 13 months of air injection bioventing. Additionally, oxygen influence monitoring was conducted on May 12-13, 1997, prior to blower shutdown, to confirm that targeted soils are receiving oxygen.

The purposes of this letter are to summarize investigation/remediation activities completed to date, to present the results of the May/June 1997 system monitoring event and compare them with the results of the initial pilot test event (March 1996), and to outline future remediation activities planned for each site. To assist review of this report by the Arkansas Department of Pollution Control and Ecology (ADPC&E), background information on the United States (US) Air Force Center for Environmental Excellence (AFCEE) project initiatives and the remedial processes associated with bioventing and natural attenuation also is provided.

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## INTRODUCTION

During 1996, under two separate contracts to AFCEE, Parsons ES conducted treatability studies at four Eaker AFB sites to determine the feasibility of remediation of petroleum contamination using bioventing for source removal and natural chemical attenuation for dissolved hydrocarbons in groundwater. Bioventing pilot testing was conducted at Spill Site No. 1, Building 457 Area, and UST 702, and a natural attenuation treatability study was conducted at the BX Service Station. The following sections provide an overview of each AFCEE project.

### AFCEE Bioventing Initiative Overview

In 1992, Parsons ES (formerly Engineering-Science, Inc. [ES]), was contracted by AFCEE to conduct bioventing pilot testing at more than 135 Air Force sites to demonstrate the feasibility of this technology for remediating petroleum-contaminated vadose zone soils. Four key objectives were established for this initiative:

- Document the effectiveness of bioventing technologies at remediating petroleum-contaminated soils in a variety of climatic, soil, and contaminant conditions.
- Use these data to complete a bioventing principles and practices manual for use by the Air Force, the Department of Defense (DOD), the US Environmental Protection Agency (USEPA), and other interested agencies.
- Promote regulatory and public acceptance of this technology.
- Begin the process of remediating fuel-contaminated sites at Air Force facilities at minimum cost to the taxpayer.

Based on favorable results from the AFCEE bioventing pilot testing initiative, AFCEE retained Parsons ES to complete remediation monitoring, full-scale bioventing system design, and/or closure sampling at sites where pilot testing was performed, and to implement pilot-scale/full-scale bioventing at several new US Air Force sites. The purpose of the new task order is to extend the operation of existing bioventing pilot-scale systems, and to move forward with either site closure or design and implementation of full-scale bioventing systems. The new task order is known as the AFCEE Extended Bioventing Project. Four potential options were identified for each site:

- Option 1 - Conduct an additional 1 year of testing for existing bioventing systems;
- Option 2 - Perform closure soil sampling for sites at which bioventing success has been demonstrated;
- Option 3 - Complete an initial bioventing test at a new site; or
- Option 4 - Design and install a multiple-vent well, full-scale bioventing system.

In March 1996, Parsons ES completed bioventing pilot testing at Spill Site No. 1, Building 457 Area, and UST 702 under the Option 3 task. Results of the pilot tests were reported August 1996 (Parsons ES, 1996). Parsons ES has also been contracted to perform two Option 1 tasks and an Option 2 task at Spill Site No. 1; an Option 1 and an Option 2 task at Building 457 Area; and an Option 1 and an Option 2 task at UST 702 at Eaker AFB. This letter report documents the results of the Option 1 tasks performed between April 1996 and June 1997. Under Option 1, Parsons ES was responsible for:

- 1) Performing any major system repairs required over 1 year of extended system operation beginning on April 4, 1996;
- 2) Collecting laboratory soil gas samples for the analysis of TVH and BTEX from the same monitoring points that were sampled during the initial sampling event;
- 3) Performing respiration testing at the same monitoring points that were tested during the initial sampling event; and
- 4) Providing AFCEE with a letter report summarizing the extended bioventing test results.

Under Option 2, Parsons ES is responsible for:

- 1) Preparing a closure sampling and analysis plan;
- 2) Performing closure soil sampling to demonstrate that site cleanup goals have been achieved; and
- 3) Preparing a soils "no-further-response-action-planned" (NFRAP) decision document or a letter report summarizing sampling results.

### **Bioventing Background**

Residual fuel contamination in soil is often a long-term source of groundwater contamination, and must be addressed to ensure complete site cleanup. A variety of *in situ* soil remediation options are now available for fuel-contaminated soils. Petroleum distillate hydrocarbons generally are biodegradable if naturally occurring aerobic microorganisms in the subsurface are provided an adequate supply of oxygen and basic nutrients. Bioventing involves low-flow soil vapor extraction and/or air injection as a means of supplying oxygen to subsurface bacteria to enhance fuel biodegradation. Parsons ES has now completed more than 175 bioventing field tests using *in situ* bioventing, and has installed more than 200 systems nationwide.

Oxygen utilization rates measured during bioventing pilot tests have been used to estimate the rates at which fuel constituents can be biodegraded *in situ*. Approximately 3.5 grams of oxygen are required to mineralize 1 gram of fuel hydrocarbons to carbon dioxide and water. This ratio likely underestimates fuel biodegradation rates because

up to a third of the fuel hydrocarbons may be used in cell production rather than carbon dioxide production. Prior field research has shown that oxygen consumption provides the most accurate indicator of bacterial respiration, which is indicative of hydrocarbon degradation.

In addition to oxygen supply, the distribution of petroleum-degrading bacteria and soil moisture conditions influence the success of *in situ* biodegradation. Adequate soil moisture also must be available to sustain microbial populations. However, excessive soil moisture can cause a reduction in air permeability, which can limit oxygen supply.

Soil bacteria also require a variety of nutrients to sustain hydrocarbon degradation. These nutrients, which include nitrogen, phosphorus, sulfur, and metals such as calcium and iron, are used by bacteria to synthesize new biomass and to manufacture enzymes. Soil bacteria must be able to obtain these nutrients from the subsurface environment. If nutrients are not available in adequate quantities, the growth of the bacterial population and the rate of hydrocarbon degradation may be limited.

Initial respiration tests at the Eaker AFB sites indicated active microbial populations at depths of up to 12 feet below ground surface (bgs) (Parsons ES, 1996). The test results therefore indicate that site conditions (e.g., soil moisture, temperature, and nutrients) are suitable for supporting these fuel-degrading bacteria.

### **AFCEE Natural Attenuation Initiative Overview**

In 1993, Parsons ES and USEPA (Robert S. Kerr Environmental Research Laboratory) were jointly contracted by AFCEE to conduct site characterization and groundwater modeling at 48 US Air Force sites to evaluate the scientific defensibility of remediation by natural attenuation (RNA) with long-term monitoring (LTM) as a remedial option for fuel- and/or solvent-contaminated groundwater. Four key objectives were established for this initiative:

- Prepare a protocol document for the evaluation of natural chemical attenuation of fuel and/or chlorinated solvents dissolved in groundwater.
- Document the ability of natural processes to remediate target volatile organic analytes dissolved in groundwater in a variety of aquifer types and hydraulic regimes, and at a range of contaminant concentrations.
- Promote regulatory and public acceptance of this technology.
- Begin the process of implementing RNA for groundwater at appropriate Air Force facilities in order to minimize cost to the taxpayer.

### **Natural Attenuation Background**

As used throughout this letter, the term "RNA" refers to a management strategy that relies on natural biological, physical, and chemical mechanisms to control exposure of receptors to concentrations of contaminants in the subsurface that could pose a threat

to human health and/or the environment. RNA is an innovative remedial approach that relies on natural chemical attenuation to remediate fuel contaminants dissolved in groundwater. Patterns and rates of RNA can vary markedly from site to site depending on governing physical, chemical, and biological processes. Mechanisms for natural attenuation of fuel hydrocarbons include advection, dispersion, dilution from recharge, sorption, volatilization, and biodegradation. Of these processes, biodegradation is the only mechanism working to remove contaminant mass by transforming the contaminants into innocuous byproducts.

Microorganisms obtain energy to replenish enzymatic systems and reproduce by oxidizing organic matter. Biodegradation of BTEX compounds is the result of a series of reduction/oxidation (redox) reactions that maintain the charge balance within the natural environment. Microorganisms facilitate the degradation of BTEX compounds by transferring electrons from the contaminants (electron donors) to available electron acceptors. Electron acceptors are elements or compounds that occur in relatively oxidized states and can participate in redox reactions involving BTEX compounds.

Microorganisms facilitate BTEX biodegradation to produce energy for their use. The amount of energy that is released when a reaction occurs or is required to drive the reaction to completion is quantified by the free energy of the reaction (Stumm and Morgan, 1981; Bouwer, 1994; Chapelle, 1993; Godsey, 1994; Mueller *et al.*, 1990). Microorganisms will only facilitate those redox reactions that will yield energy. Microorganisms are able to utilize electron transport systems and chemiosmosis to combine energetically favorable and unfavorable reactions to produce energy for life processes. By coupling the oxidation of BTEX compounds, which requires energy, to the reduction of other compounds (e.g., oxygen, nitrate, manganese, ferric iron, sulfate, and carbon dioxide), which yields energy, the overall reaction will yield energy.

Figure 1 (attached) illustrates the sequence of microbially mediated redox processes based on the amount of free energy released for microbial use. In general, reactions yielding more energy tend to take precedence over processes that yield less energy (Stumm and Morgan, 1981; Godsey, 1994; Reinhard, 1994). As Figure 1 (attached) shows, oxygen reduction would be expected to occur first in an aerobic environment because oxygen reduction yields more energy than any other reaction (Bouwer, 1992; Chapelle, 1993). However, once the available oxygen is depleted and anaerobic conditions dominate the interior regions of the contaminant plume, anaerobic microorganisms can utilize other electron acceptors in the following order of preference: nitrate, manganese, ferric iron, sulfate, and finally carbon dioxide. Each successive redox reaction provides less energy to the system, and each step down in redox energy yield would have to be paralleled by an ecological succession of microorganisms capable of facilitating the pertinent redox reactions.

To estimate the impact of RNA on the fate and transport of BTEX compounds dissolved in groundwater at the site, two important lines of evidence should be demonstrated (Wiedemeier *et al.*, 1995). The first is a documented loss of contaminants at the field scale. One way to show loss of contaminant mass is to use

historical monitoring data to show that plume concentrations and extents have decreased or remained constant over time. The second line of evidence involves the use of geochemical data in mass-balance calculations to show that areas with fuel contamination can be correlated to areas with depleted electron acceptor (e.g., dissolved oxygen, nitrate, and sulfate) concentrations and increases in metabolic fuel degradation byproduct concentrations (e.g., methane and ferrous iron). With this site-specific information, groundwater flow and solute transport data can be used to estimate the extent of RNA occurring in site groundwater.

During March 1996, Parsons ES performed a treatability study in support of RNA for the BX Shoppette (Site E11) at Eaker AFB (Parsons ES, 1997). Because subsurface conditions and aquifer parameters at the BX Shoppette are similar to those of the bioventing sites at Eaker AFB, data collected and conclusions made during this study are considered to be relevant to the conditions that are expected at the bioventing sites. Geochemical data collected during this treatability study suggested that biodegradation of fuel hydrocarbons is occurring in both site aquifers via aerobic respiration and the anaerobic processes of iron reduction, manganese reduction, sulfate reduction, and methanogenesis. Combined anaerobic processes accounted for 89 percent of the BTEX expressed assimilative capacity of shallow site groundwater.

As with a large number of biological processes, anaerobic fuel biodegradation rates can generally be described using a first-order rate constant, estimated as:

$$\frac{C}{C_0} = e^{-kt}$$

where:  $C$  = Contaminant concentration at time  $t$ ,  
 $C_0$  = Initial contaminant concentration,  
 $k$  = Anaerobic decay coefficient (anaerobic rate constant), and  
 $t$  = time.

Two methods of calculating rate constants are currently available to quantify rates of biodegradation at the field scale. The first method involves the use of a biologically recalcitrant compound found in dissolved fuel contaminant plumes as a conservative tracer. The second method, proposed by Buscheck and Alcantar (1995), involves interpretation of a steady-state contaminant plume configuration and is based on the one-dimensional, steady-state analytical solution to the advection-dispersion equation presented by Bear (1979). Using the Buscheck and Alcantar method, a first-order decay rate of 0.0062 day<sup>-1</sup> was calculated for the BX Shoppette (Parsons ES, 1997).

## SITE REMEDIATION HISTORY

Spill Site No. 1 is located near former Pumphouse No. 4 (Building 1020), (Figure 2, attached). Four 50,000-gallon underground storage tanks (USTs) containing jet

propulsion fuel grade 4 (JP-4) were formerly located northeast and southwest of Pumphouse No. 4. Ten- and 6-inch pipelines were used to transfer fuel from the four tanks to the aircraft fueling hydrants on the flight apron. Pressure testing of the fuel hydrant system, performed in 1973, indicated the presence of a leak in the 6-inch fuel line, northwest of Pumphouse No. 4 (Halliburton NUS [HNUS], 1994), and the system was subsequently taken out of service. The USTs and Building 1020 were removed in 1995, and the fuel lines were abandoned in place. The site is currently vacant and inactive. Figure 2 (attached) presents the layout of Spill Site No. 1, and illustrates the locations of monitoring wells (MWs), vent wells (VWs), soil vapor monitoring points (MPs), and the bioventing regenerative blower system.

Building 457 is located west of Spill Site No. 1, and was formerly used as a fuel cell maintenance and repair shop (US Air Force, 1995). A 20,074-gallon steel UST used to store heating oil, located at the northwest corner of Building 457, was removed in August 1994 (Ogden Environmental and Energy Service [Ogden], 1995). Analytical results for soil samples taken from the sidewalls of the excavation pit indicated that all contaminated soil had not been removed. Figure 3 (attached) presents the layout of Building 457 Area, and illustrates the locations of MWs, VWs, MPs, and the bioventing regenerative blower system.

Former UST 702 was located adjacent to Building 702 in the west-central portion of the Base. The former 2,010-gallon tank, used to store heating oil that was used for heating Building 702, was removed in June 1994 (Ogden, 1995). Although the tank was over excavated, tank removal soil sampling results confirmed that not all contaminated soil had been removed from the site (US Air Force, 1995). Figure 4 (attached) presents the layout of the UST 702 site, and illustrates the locations of MWs, VWs, MPs, and the bioventing regenerative blower system.

Following tank removals, subsurface investigations at these sites were performed in 1995 by HNUS (1996). In March and April 1996, pilot-scale bioventing systems were installed at each site by Parsons ES as part of the AFCEE Extended Bioventing Project (Option 3). At Spill Site No. 1, the installed pilot-scale bioventing system consisted of six VWs (VW1 through VW6), five soil vapor MPs (MPA, MPB, MPC, MPD, and MPE), and a regenerative blower unit configured for air injection into all six VWs (Figure 2). At Building 457 Area, the installed pilot-scale bioventing system consisted of two VWs (TW1503 [VW1] and TW1501 [VW2]), three soil vapor MPs (MPA, MPB, and MPC), and a regenerative blower unit configured for air injection into both VWs (Figure 3). At UST 702, the installed pilot-scale bioventing system consisted of one VW (TW1601), three MPs (MPA, MPB, and MPC), and a regenerative blower unit configured for air injection into the VW (Figure 4). During the installation of the pilot-scale systems, soil and soil gas sampling, and respiration and air permeability testing were performed. Petroleum-contaminated soil and/or soil gas was encountered at all sampled locations at each site. Details of system installation and initial analytical results are presented in the interim bioventing pilot test results report (Parsons ES, 1996).

Under the Extended Bioventing Project, Spill Site No. 1 was allocated funding for 2 years of system maintenance with year-end respiration testing and soil gas sampling (Option 1), and for site closure (Option 2). Building 457 Area and UST 702 were allocated funding for 1 year of system maintenance with year-end testing (Option 1) and for site closure (Option 2). This letter reports the Option 1 year-end testing events for Spill Site No. 1, Building 457 Area, and UST 702. In addition to the Option 1 tasks (listed on pages 2 and 3), several soil and groundwater samples were collected from each site to support eventual site closures.

## OPTION 1 TESTING RESULTS

### Spill Site No. 1 Summary

On May 13, 1997, Parsons ES conducted oxygen influence monitoring at Spill Site No. 1 to confirm that the targeted soil zone was being provided with an adequate supply of oxygen. Following oxygen influence monitoring, the blower system was shut off to allow soil gas conditions to equilibrate with the soils prior to soil gas sampling for laboratory analysis. During the week of June 15, 1997, Parsons ES remobilized to the site to conduct additional site investigation work and to perform annual respiration testing and soil gas sampling.

Sampling and analysis at Spill Site No. 1 focused on filling data gaps by better defining the FAE of petroleum contamination in soil, soil gas, and groundwater. Parsons ES advanced five Geoprobe borings (MPF, MPG, MPH, MPI, and SB7) to varying depths corresponding to the smear zone. Four of the Geoprobe borings were converted for use as soil vapor MPs (MPF-8.5, MPG-6, MPH-8, and MPI-8). A temperature thermocouple was installed in MPG at a depth of 6 feet bgs. Four vadose zone soil samples were collected from Geoprobe borings MPF, MPG, MPI, and SB7, and analyzed for BTEX by USEPA Method SW8020.

Following MP installation, Parsons ES collected soil gas samples from each vapor MP, VW, and existing monitoring well and field analyzed each sample for oxygen, carbon dioxide, and TVH. Based on field screening results, Parsons ES collected eight soil gas samples for laboratory analysis from new and existing MPs. Soil gas samples were analyzed for BTEX and TVH by USEPA Method TO-3. Respiration testing was then conducted at MPA-9, MPB-9, and MPD-9. Oxygen utilization rates were still significant at all testing locations. While conducting the respiration test, Parsons ES also sampled five existing groundwater monitoring wells for geochemical parameters to support an evaluation of RNA.

On June 20, 1997, following the respiration test and groundwater sampling, the blower system was turned on and reoptimized. After turning the blower on, it was discovered that VW4 is slightly damaged. Air injection to VW4 was turned off and the well remains damaged. On September 4, 1997 the 2-horsepower (HP) blower ceased to operate due to a frozen bearing in the motor (Looney, 1997a). On September 17, 1997, Parsons ES was notified that electrical power to the bioventing blowers at Eaker AFB will not be available until further notice (Looney, 1997b). An upgraded 3-HP

Gast<sup>®</sup> regenerative blower system was delivered to Eaker AFB on September 22, 1997. The new blower motor will be installed and VW4 will be repaired by Parsons ES after electrical power is restored. Parsons ES proposes to reclaim the damaged 2-HP blower for possible use on another Eaker AFB project, assuming that the blower can be repaired cost effectively. The motor on the damaged blower is repairable; however, shipping and repair costs may exceed the replacement cost to Parsons ES. With Base and AFCEE concurrence, Parsons ES will transport the blower to Denver for possible repairs following the next field mobilization.

The following sections provide details on the current sampling results and summarize previous site investigation data. Figure 2 (attached) shows the locations of the six VWs, nine MPs, blower unit, and other soil borings and groundwater monitoring wells at the site. Tables 1 through 6 (attached) summarize recent and previously collected data.

### **Soil Sampling Results**

Table 1 (attached) summarizes soil analytical results for Spill Site No. 1. Several historic shallow soil samples with non-detectable BTEX concentrations are not listed on the table. During June 1997, Parsons ES collected four vadose zone soil samples from Geoprobe borings MPF, MPG, MPI, and SB7 at depths immediately above the saturated zone. Samples were submitted under chain-of-custody control to Intertek Testing Services (ITS) in Richardson, Texas. Samples were analyzed for BTEX using USEPA Method SW8020. SB7 contained low detectable concentrations of each BTEX compound. Photoionization detector (PID) results for the headspace of a soil sample collected at 8 feet bgs from MPH, and laboratory TVH results indicate that this location is within the FAE of petroleum contamination. Sampling results indicate that MPF, MPG, and SB7 are outside the area of contamination.

Based on the data presented in Table 1, the lateral FAE of BTEX contamination in vadose zone soils is bounded by MW205 (VW6), MPF, SB209, SB206, MPG, MW204, MW201, MW202, SB7 (1997), MW207, and SB211 (Figure 2). Soil analytical results indicate that the area adjacent to MW202 is not significantly contaminated; however, soil gas analytical results for MPH and MPI (see discussion below) indicate that this area is oxygen depleted and contains high TVH levels (>50,000 parts per million, volume per volume [ppmv]). Therefore, future system modifications should be made to provide air injection into monitoring well MW202.

### **Oxygen Influence Monitoring**

To confirm that the targeted soil zone at Spill Site No. 1 was being sufficiently oxygenated, Parsons ES performed oxygen influence monitoring on May 13, 1997, prior to shutting off the blower system. Table 2 (attached) presents the changes in soil gas oxygen levels that occurred during a 13-month air injection period. Based on soil gas changes observed at MPE-9.5 and MW203 it appears that the radius of oxygen influence (ROI) within the deep soil zone (5-10 feet bgs) is at least 32 feet, and may be as much as 40 feet in some locations. Available data are inconclusive for determining

the actual ROI for the "tight" shallow soils (1-5 feet bgs). No oxygen influence was observed at MPD-5, which is located approximately 29 feet from VW3 (Figure 2). This may be due to preferential flow of injected air into the fuel pipeline corridor, located between VW3 and MPD, or to "tight" soils. VW4 was damaged sometime between May 1996 and May 1997; therefore, no oxygen influence was observed at MW207. Following oxygen influence testing, the blower was shut down for 1 month to allow soil gas conditions to equilibrate before soil gas sampling was conducted.

### Soil Gas Chemistry Results

Soil gas samples were collected for field screening and laboratory analysis at Spill Site No. 1 in June 1997, 1 month following blower shutdown on May 13, 1997. Soil gas sampling results from this Option 1 testing event, as well as soil gas sampling results from the initial testing event (March 1996), are presented in Table 3 (attached). During the June 1997 sampling event, static soil gas oxygen concentrations were below 5 percent at all MPs except MPC-5, indicating that significant oxygen demand still exists in the soils, and that aerobic fuel biodegradation is still occurring at significant rates. High oxygen levels at VW2, VW3, VW4, and VW5 are the result of long-term air injection at these wells; most of the fuel contamination initially present at these locations has been aerobically biodegraded or has volatilized and migrated away from the injection point via soil gas advection. Significant reductions in soil gas TVH concentrations at VW4 indicate that the well may have been damaged for only a short time prior to year-end testing.

Soils at VW5 are only slightly contaminated with petroleum hydrocarbons, and the high oxygen concentration at this point reflects the lack of substrate (i.e., fuel hydrocarbons) in soils. Generally, field soil gas TVH concentrations have decreased at most deep MPs (8-9 bgs), however, it appears that volatile organic compounds (VOCs) are being driven up into the shallow clay zone (5 feet bgs), based on the increased TVH concentrations at MPB-5 and MPC-5. Fuel residuals in shallow soils will gradually biodegrade as injected air and atmospheric oxygen diffuse into the shallow soils. Also, precipitation percolating through the tight, shallow soils will leach residual contaminants out of the clayey soil matrix and into the deeper more permeable silty clay zone, which is sufficiently oxygenated. TVH concentrations at or exceeding 10,000 ppmv were detected at five sampling locations, indicating that significant levels of volatile petroleum hydrocarbons remain in site soils.

Soil gas samples collected at MPA-9, MPB-8.5, MPC-5, MPD-9, MPE-9.5, MPF-8.5, MPH-8, and MPI-8 were submitted under chain-of-custody to the Air Toxics, Ltd. laboratory in Folsom, California, and analyzed for TVH and BTEX using USEPA Method TO-3. At all locations except MPA-9 and MPF-8.5, TVH levels in soil gas were high, ranging from 5,700 to 68,000 ppmv. Although TVH levels remained high in some locations, significant decreases in soil gas BTEX concentrations were noted at MPA-9 (92-percent reduction) and MPD-9 (69-percent reduction). These data indicate that although TVH levels at Spill Site No. 1 are very high, the risk-driving BTEX compounds are being preferentially destroyed by bioventing system operation.

## Respiration Testing Results

After the soil gas sampling was completed at Spill Site No. 1, an *in situ* respiration test was performed according to procedures outlined in the AFCEE bioventing protocol document (Hinchee *et al.*, 1992). Air was injected for 15 hours into MPA-9 and MPB-9, and for 35.5 hours into MPD-9 using 1-cubic-foot-per-minute (cfm) pumps to locally oxygenate the soils. An attempt was made to conduct respiration testing at MPC-5, MPC-9, and MPD-5; however, the soils were either too tight to induce air flow with the small 1-cfm pumps, or the MP screen was submerged in groundwater. Following the air injection period, changes in soil gas oxygen, carbon dioxide, and TVH concentrations were monitored for at least 9 hours. Observed rates of oxygen utilization were then used to estimate aerobic fuel biodegradation rates. Table 4 (attached) presents the results of respiration testing performed at Spill Site No. 1 in March 1996 and June 1997.

Oxygen utilization rates were still significant at all testing locations. Oxygen utilization rates at testing points ranged from 1.16 to 2.68 percent per hour, with estimated fuel biodegradation rates ranging from 1,870 to 4,310 milligrams total petroleum hydrocarbons (TPH) per kilogram soil per year (mg/kg/yr). Oxygen consumption rates in June 1997 were slightly higher than they had been during initial testing, indicating that a significant amount of fuel hydrocarbons remain in soils, and that fuel biodegradation will continue to be enhanced by air injection bioventing. Soil moisture content likely was higher during the June 1997 testing, so actual biodegradation rates at MPA-9, MPB-9, and MPD-9 may have been slightly lower than those indicated during the initial testing. Future respiration testing will be conducted at MPA-9, MPB-9, MPC-9, MPD-9, and MPI-8, unless the MP is submerged under groundwater.

## Natural Attenuation Monitoring

During the June 1997 field activities, Parsons ES also collected 5 groundwater samples from Spill Site No. 1 to evaluate the RNA of jet fuel dissolved in groundwater. Several groundwater sampling events conducted at Spill Site No. 1 prior to June 1997 indicated the presence of benzene above the ADPC&E maximum contaminant level (MCL) of 5  $\mu\text{g}/\text{L}$ . Table 5 (attached) summarizes most of the historic site analytical data for groundwater samples. Of seven groundwater grab samples collected by HNUS (1992), only sample GW202 contained detectable concentrations of VOCs. Ten groundwater monitoring wells in the shallow aquifer were sampled by HNUS (1995) from June through August 1995. BTEX compounds were detected in two of the wells (MW205 and MW211). These samples also were analyzed for semi-volatile aromatic hydrocarbons by USEPA Method SW8270, metals, and several geochemical parameters.

During the June 1997 (Option 1) field event, Parsons ES collected groundwater samples from site groundwater monitoring wells MW204, MW211, MW206, MW207, and MW208 and background monitoring well MW010. Groundwater samples were analyzed by Parsons ES personnel in the field for alkalinity, dissolved oxygen (DO),

ferrous iron, free carbon dioxide, pH, redox potential, nitrate, soluble manganese, sulfate, and temperature. The results of these analyses are provided in Table 6 (attached). Samples for analysis of BTEX by USEPA Method SW8020 and methane by USEPA Method RSKSOP-175M were shipped via Federal Express to Evergreen Analytical Laboratory (EAL) in Wheat Ridge, Colorado, and results are summarized in Table 5. Groundwater samples were collected and analyzed according to the protocol developed for the AFCEE Natural Attenuation Initiative (Wiedemeier *et al.*, 1995).

In June 1997, the highest BTEX concentration (298 micrograms per liter [ $\mu\text{g}/\text{L}$ ]) was detected at well MW211, which is located in the source area. The only other time this well was sampled, total BTEX concentrations were lower. Monitoring well MW207 is the only other well where a BTEX compound was detected (xylanes were detected at the detection limit). In the past, the highest BTEX concentrations were detected at MW203; however, this well was damaged and could not be sampled in June 1997. Because of the limited contaminant distribution and the limited number of sampling events, the loss of contaminant mass from the system could not be definitively documented. Nevertheless, based on available groundwater analytical data, the maximum downgradient extent of dissolved BTEX contamination is estimated to be approximately 100 feet from the former USTs.

Geochemical data collected during June 1997 suggest that biodegradation of fuel hydrocarbons at Spill Site No. 1 is occurring in the shallow aquifer via aerobic respiration and the anaerobic processes of iron reduction, sulfate reduction, denitrification, and methanogenesis (Table 6). The data indicates that the electron acceptors oxygen, nitrate, and sulfate are present at lower concentrations in the source area than background. Also, the metabolic byproducts ferrous iron and methane are present at higher concentrations in the source area than background.

Assuming a first-order decay rate of  $0.0062 \text{ day}^{-1}$  (reported value for the BX Shoppette), the BTEX half-life is approximately 112 days. To estimate the time required for Spill Site No. 1 groundwater to meet the state MCL for benzene assuming biodegradation alone, the equation  $C = C_0 e^{-kt}$  is solved for "t". Solving for "t", benzene concentrations should theoretically decrease from a concentration of  $130 \mu\text{g}/\text{L}$  to  $5 \mu\text{g}/\text{L}$  in approximately 525 days, assuming that the bioventing system successfully prevents further partitioning of benzene from site soils into groundwater and assuming that each BTEX compound is degraded at the same rate. The assumed decay rate is lower than decay constants frequently reported in literature, and therefore is considered conservative (Chapelle, 1994; Wilson *et al.*, 1994; Stauffer *et al.*, 1994). Nevertheless, some petroleum hydrocarbons will remain sorbed to saturated soil following bioventing treatment; therefore, dissolved contamination may persist longer than 525 days.

Considering the age of the contaminants, expected reductions in contaminant leaching from source area soils, and the effects of natural attenuation, it is likely that the dissolved BTEX plume is shrinking. LTM will clarify the status of the plume. At the very least, MW211 should be sampled annually, until benzene concentrations drop below  $5 \mu\text{g}/\text{L}$ . Current Base policy does not allow the extraction of shallow

groundwater for potable uses. Therefore, contaminated groundwater will not be used by onsite receptors.

## **Recommendations**

This section provides recommendations for future remedial actions at Spill Site No. 1.

1. Parsons ES is currently under contract to provide 1 additional year of bioventing system operation and maintenance, followed by site closure activities (if appropriate).

### Long-Term Groundwater Monitoring

To continue to monitor the effectiveness of natural processes at reducing contaminant concentration, mass, mobility, and toxicity in affected media, it is recommended that a groundwater monitoring plan be developed and implemented at Spill Site No. 1. Long-term groundwater monitoring is essential for verification of natural chemical attenuation progress and confirmation that the local hydrogeology and natural biodegradation are retarding plume migration. As part of an LTM plan, contaminant behavior in groundwater over time would be monitored to verify that the proposed remedial alternative (i.e., natural chemical attenuation, LTM, bioventing, land and groundwater use controls, and public education) is sufficient to protect human health and the environment. The number of existing groundwater monitoring wells at Spill Site No. 1 appears to be sufficient for providing information on the areal extent and concentrations of groundwater contamination.

### Verification of Current and Future Land and Groundwater Use Controls

An important element of the remedial action for Spill Site No. 1 is groundwater use controls. Any future lease or new use of this land should stipulate that shallow groundwater will not be extracted within 1,000 feet of the plume centerline until BTEX concentrations meet state groundwater quality standards. The site should be acceptable for future industrial use if contaminated soils remain undisturbed.

### Continued Bioventing System Operation and Maintenance

Based on the positive results obtained during bioventing pilot testing at Spill Site No. 1, the following recommendations are proposed to attain cleanup goals:

- Continue bioventing system operation with annual respiration testing/soil gas sampling to determine remedial progress;
- Install buried piping for air injection into existing well MW202;
- Develop and negotiate risk-based cleanup criteria with ADPC&E for eventual site closure.

## Building 457 Area Summary

On May 13, 1997, Parsons ES conducted oxygen influence monitoring at Building 457 Area to confirm that the targeted soil zone was being provided with an adequate supply of oxygen. Following oxygen influence monitoring, the blower system was shut off to allow soil gas conditions to equilibrate with the soils prior to soil gas sampling for laboratory analysis. During the week of June 15, 1997, Parsons ES remobilized to the site to conduct additional site investigation work and to perform annual respiration testing and soil gas sampling.

Sampling and analysis at Building 457 Area focused on filling data gaps by better defining the FAE of petroleum contamination in soil and groundwater. Parsons ES advanced six soil borings (SB6 through SB11) with a Geoprobe rig. Four of the borings (MPB, SB8, SB10, and SB11) were advanced to depths corresponding to the bottom of the former UST, and two borings (SB7 and SB9) were drilled to investigate vadose zone contamination. One vadose zone soil sample was analyzed for BTEX by USEPA Method SW8020 and for total extractable petroleum hydrocarbons (TEPH) by USEPA Method SW8015 modified, and two saturated zone soil samples were analyzed for BTEX (SW8020) and for polynuclear aromatic hydrocarbons (PAHs) by USEPA Method SW8310.

Because only one of the borings (MPB) exhibited vadose zone contamination, additional vapor MPs were not installed. Following drilling activities Parsons ES collected soil gas samples from each vapor MP, VW, and existing monitoring wells and field analyzed each sample for oxygen, carbon dioxide, and TVH. To determine remedial progress, soil gas samples for laboratory analysis of BTEX and TVH by USEPA Method TO-3 were collected from MPA-5.5, MPB-5, and MPC-4.5. After soil gas samples were collected, a respiration test was conducted at MPB-5 and MPC-4.5. Oxygen utilization rates were still significant at both testing locations. To evaluate the potential for RNA of dissolved organics in groundwater, groundwater samples also were collected from wells TW1502 and TW1504 for field and laboratory analysis.

On June 21, 1997, following the respiration test and groundwater sampling, the blower system was turned on and reoptimized. On September 17, 1997 Parsons ES was notified that electrical power to the bioventing blowers at Eaker AFB will not be available until further notice (Looney, 1997b). The blower system will be reoptimized by Parsons ES after electrical power is restored.

The following sections provide details on the current sampling results and summarize previous site investigation data. Figure 3 (attached) shows the locations of the two VWs, three MPs, blower unit, and other soil borings and groundwater monitoring wells at the site. Tables 7 through 12 (attached) summarize recent and previously collected data.

## Soil Sampling Results

Table 7 (attached) summarizes soil analytical results for Building 457 Area. During June 1997, Parsons ES collected four saturated zone soil samples from Geoprobe borings SB8 and SB11, at depths corresponding to the bottom of the former UST. One saturated soil sample from each boring was analyzed for BTEX using USEPA Method SW8020 and for PAHs using USEPA Method SW8310. To determine remedial progress after 13 months of bioventing treatment, a vadose zone soil sample was collected from near MPB at a depth of 5 feet bgs, and analyzed for BTEX (SW8020), and for TEPH using USEPA Method SW8015 modified. Samples were submitted under chain-of-custody control to the ITS laboratory.

At MPB, TEPH and BTEX concentrations were slightly lower during the June 1997 sampling than during the March 1996 sampling event. This apparent contaminant reduction may be due to sampling variabilities that are encountered over small distances or due to sampling and analytical variabilities. Also, comparison of initial and 1-year soil and soil gas analytical results at MPB suggests that the significant groundwater fluctuations that occurred during the first year of bioventing caused smearing of petroleum hydrocarbons. *In situ* respiration tests are considered to be better indicators of hydrocarbon remediation than limited soil sampling. Therefore, the limited soil analytical results obtained from MPB during the initial and 1-year testing should not be viewed as conclusive indicators of bioventing progress or evidence of the success or failure of this technology. Shallow soil samples collected from borings SB7, SB8, SB9, SB10, and SB11 (Figure 3) exhibited no visible or olfactory evidence of vadose zone contamination. Based on review of soil analytical data, it appears that the horizontal FAE of vadose zone contamination is limited to the area immediately south of the former tank excavation (near VW1). Based on comparison of initial and 1-year soil and soil gas analytical results, it appears that significant groundwater fluctuations that occurred during the first year of bioventing caused smearing of petroleum hydrocarbons.

## Oxygen Influence Monitoring

To confirm that the targeted soil zone at Building 457 Area was being sufficiently oxygenated, Parsons ES performed oxygen influence monitoring on May 13, 1997, prior to shutting off the blower system. Table 8 (attached) presents the changes in soil gas oxygen levels that occurred during the 13-month air injection period. Based on significant soil gas changes observed at MPC-4.5 it appears that the ROI within the shallow soil zone (1-6 feet bgs) is at least 25 feet, and may be as much as 30 feet.

## Soil Gas Chemistry Results

One month after the bioventing blower was shut down, soil gas samples were collected for field screening and laboratory analysis at Building 457 Area in June 1997. Soil gas sampling results from this Option 1 testing event, as well as soil gas sampling results from the initial March 1996 testing event, are presented in Table 9 (attached). During the June 1997 sampling event, static soil gas oxygen concentrations were below

5 percent at all MPs, indicating that significant oxygen demand still exists in the soils, and that aerobic fuel biodegradation is still occurring at significant rates. Higher oxygen levels at VW1 and VW2 are the result of long-term air injection at these wells; most of the fuel contamination initially present at these locations has been aerobically biodegraded or has volatilized and migrated away from the injection point via soil gas advection. At all locations except MPB-5, June 1997 field TVH levels in soil gas were still low, ranging from 52 to 380 ppmv.

Soil gas samples collected at MPA-5.5, MPB-5, and MPC-4.5 were submitted under chain-of-custody to Air Toxics, Ltd. laboratory and analyzed for TVH and BTEX using USEPA Method TO-3. At MPB-5 and MPC-4.5, laboratory soil gas TVH concentrations increased due to the "smearing effect" of groundwater fluctuation. Laboratory TVH concentrations exceeding 400 ppmv were detected only at MPB-5, indicating that low levels of volatile petroleum hydrocarbons still exist at discrete locations in vadose zone soils. Although laboratory TVH levels at MPB are somewhat elevated, concentrations of the risk-driving BTEX compounds are low (Table 9).

A soil gas sample for field analysis was also collected from newly installed monitoring well MW092, which is located within the Building 410 area (410 Area), adjacent to Building 457 Area (Figure 3). A low oxygen level (0.9 percent) and high TVH concentration (20,000 ppmv) at this location indicates that the soils within the 410 Area are petroleum-contaminated, and that oxygen depletion is limiting natural biodegradation. The 410 Area formerly contained several USTs and ASTs that were the likely source of contamination at well MW092.

### Respiration Testing Results

After the soil gas sampling was completed at Building 457 Area, an *in situ* respiration test was performed according to procedures outlined in the AFCEE bioventing protocol document (Hinchee *et al.*, 1992). Air was injected for 16 hours into MPB-5, and MPC-4.5 using 1-cfm pumps to locally oxygenate the soils. An attempt was made to conduct respiration testing at MPA-5.5, however, the MP screen was submerged in groundwater. Following the air injection period, changes in soil gas oxygen, carbon dioxide, and TVH concentrations were monitored for at least 9 hours. Observed rates of oxygen utilization were then used to estimate aerobic fuel biodegradation rates. Table 10 (attached) presents the results of respiration testing performed at Building 457 Area in March 1996 and June 1997.

Oxygen utilization rates were still significant at all testing locations, ranging from 2.41 to 2.57 percent per hour, with estimated TPH biodegradation rates ranging from 1,130 to 1,210 mg/kg/yr. Oxygen consumption rates in June 1997 were slightly lower than they had been during initial testing, indicating that a significant amount of fuel hydrocarbons remains in soils, and that fuel biodegradation will continue to be enhanced by air injection bioventing. Soil moisture content was likely higher during the June 1997 testing, so actual biodegradation rates at MPB-5 and MPC-4.5 may have been slightly lower than reported estimates. A final respiration test should be conducted at each MP, prior to closure soil sampling.

## Natural Attenuation Monitoring

During the June 1997 (Option 1) field event, Parsons ES collected groundwater samples from two site monitoring wells (TW1502 and TW1504) and one background monitoring well (MW010) to evaluate the RNA of heating oil constituents in groundwater. Table 11 (attached) summarizes historic site laboratory analytical data for groundwater samples. In June 1997, groundwater samples were analyzed by Parsons ES personnel in the field for alkalinity, DO, ferrous iron, free carbon dioxide, pH, redox potential, nitrate, soluble manganese, sulfate, and temperature. The results of these geochemical analyses are provided in Table 12 (attached). Samples for analysis of BTEX by USEPA Method SW8020 and PAHs by USEPA Method SW8310 were shipped via Federal Express to EAL in Wheat Ridge, Colorado, and results are summarized in Table 11 along side the historic results. Groundwater samples were collected and analyzed according to the protocol developed for the AFCEE Natural Attenuation Initiative (Wiedemeier *et al.*, 1995). Based on available groundwater analytical data, it appears that groundwater at the site is not contaminated above state groundwater MCLs.

Considering the contaminant type (heating oil), it is not surprising that the groundwater at Building 457 Area is already below state groundwater MCLs for BTEX, and below American Society for Testing and Materials (ASTM, 1995) Risk-Based Corrective Action (RBCA) guidance levels for BTEX, naphthalene, and benzo(a)pyrene. The limited geochemical data collected during June 1997 suggest that biodegradation of fuel hydrocarbons at Building 457 Area may be occurring in the shallow aquifer via aerobic respiration and the anaerobic processes of iron reduction and denitrification. Follow-up groundwater sampling for BTEX and PAH analysis should be performed at wells TW1501 and TW1503 to confirm that groundwater at the air injection VWs are below ASTM (1995) RBCA standards.

Considering the type and limited extent of contamination at Building 457 Area, groundwater LTM is not recommended other than to confirm the absence of groundwater contamination at wells TW1501 and TW1503.

## Recommendations

Based on the respiration testing results, and the 1-year soil sampling results from Building 457 Area, it is recommended that the bioventing system remain in operation until April 1998, and that Option 2 closure sampling be performed at that time. Upon AFCEE concurrence, Parsons ES will begin to develop a confirmation sampling and analysis plan for Building 457 Area. As an initial step, the ADPC&E will be contacted to determine if any additional information is needed to obtain closure, or if the site can be closed based on soil and groundwater analytical data already available. Although a significant amount of residual fuel hydrocarbons remain in soils at this site, the BTEX compounds are present at very low concentrations (Tables 7 and 9).

Based on the positive results from bioventing pilot testing at Building 457 Area, the following recommendations are proposed to obtain site closure:

- Continue bioventing system operation with year-end respiration testing/soil gas sampling to confirm remedial success;
- Proceed with site closure activities, including preparation of a confirmation sampling and analysis plan; (e.g., collect soil and groundwater samples to confirm remedial success, if necessary);
- Negotiate risk-based cleanup criteria with ADPC&E for site closure; and
- Future lease or development of the area should contain use restrictions to prevent groundwater pumping, to protect existing groundwater wells to the extent possible, and to minimize contact with contaminated soils.

## UST 702 Summary

On May 12, 1997, Parsons ES conducted oxygen influence monitoring at UST 702 to confirm that the targeted soil zone was being provided with an adequate supply of oxygen. Following oxygen influence monitoring, the blower system was shut off to allow soil gas conditions to equilibrate with the soils prior to soil gas sampling for laboratory analysis. During the week of June 15, 1997, Parsons ES remobilized to the site to conduct additional site investigation work and to perform annual respiration testing and soil gas sampling.

Sampling and analysis at UST 702 focused on filling data gaps by better defining the FAE of petroleum contamination in soil and groundwater. Parsons ES advanced four soil borings (MPB, SB13, SB14, and SB15) with a Geoprobe rig. Each of the borings was advanced to depths corresponding to the bottom of the former UST. One vadose zone soil sample was analyzed for BTEX by USEPA Method SW8020 and for TEPH by USEPA Method SW8015 modified, and four saturated zone soil samples were analyzed for BTEX (SW8020), and for PAHs by USEPA Method SW8310.

Following drilling activities, Parsons ES collected soil gas samples from each vapor MP, VW, and existing monitoring wells and field analyzed each sample for oxygen, carbon dioxide, and TVH. To determine remedial progress, a soil gas sample for laboratory analysis of BTEX and TVH by USEPA Method TO-3 was collected from MPB-5. After the soil gas sample was collected, a respiration test was conducted at MPB-5. Oxygen utilization rates were still significant at the testing location. To evaluate the potential for RNA of dissolved organics in groundwater, groundwater samples from wells TW1601, TW1602, TW1604, and TW1604 also were collected for field and laboratory analysis.

On June 21, 1997, following the respiration test and groundwater sampling, the blower system was turned on and reoptimized. On September 17, 1997, Parsons ES was notified that electrical power to the bioventing blowers at Eaker AFB will not be available until further notice (Looney, 1997b). The blower system will be reoptimized by Parsons ES after electrical power is restored.

The following sections provide details on the current sampling results and summarize previous site investigation data. Figure 4 (attached) shows the locations of the VW, three MPs, blower unit, and other soil borings and groundwater monitoring wells at the site. Tables 13 through 18 (attached) summarize recent and previously collected data.

### **Soil Sampling Results**

Table 13 (attached) summarizes all soil analytical results collected to date for UST 702. During June 1997, a vadose zone soil sample was collected adjacent to MPB at a depth of 5 feet bgs to determine the level of cleanup achieved after 1 year of remediation at the site. Soil samples were submitted under chain-of-custody control to the ITS laboratory. At MPB, TEPH and BTEX concentrations were lower during the June 1997 sampling than during the March 1996 sampling event. This apparent contaminant reduction may be due to soil heterogeneities that are encountered over small distances or due to sampling and analytical variabilities. Also, comparison of initial and 1-year soil and soil gas analytical results for MPB suggests that the significant groundwater fluctuations that occurred during the first year of bioventing caused smearing of petroleum hydrocarbons. *In situ* respiration tests are considered to be better indicators of hydrocarbon remediation than limited soil sampling. Therefore, the limited soil analytical results obtained from MPB during the initial and 1-year testing should not be viewed as conclusive indicators of bioventing progress or evidence of the success or failure of this technology. Based on previous and recent soil screening results and review of soil analytical data (Table 13), it appears that the FAE of contamination in vadose zone soils is limited to soils located near the MPs.

Four saturated soil samples also were collected during June 1997, to determine the presence or absence of BTEX and PAH compounds at depths corresponding to the bottom of the former tank excavation. Saturated zone soil samples were collected from Geoprobe borings MPB, SB13, SB14, and SB15. Several PAH compounds (including phenanthrene, fluoranthene, and pyrene) were detected in saturated soil samples collected from 18 to 20 feet bgs at MPB and from 17 to 18.5 feet at SB15. BTEX compounds were detected only in the soil samples collected from MPB. Based on soil screening results and review of soil analytical data (Table 13), it appears that the FAE of contamination in saturated zone soils is limited to soils located near the MPs.

### **Oxygen Influence Monitoring**

To confirm that the targeted soil zone at UST 702 was being sufficiently oxygenated, Parsons ES performed oxygen influence monitoring on May 12, 1997, prior to shutting down the blower. Table 14 (attached) presents the changes in soil gas oxygen levels that occurred during a 13-month air injection period. Initial (March 1996) soil gas oxygen concentrations at MPA-5.5 and MPC-4.5 were ambient, therefore, oxygen influence measurements were not collected from these MPs. Based on significant soil gas changes observed at MPB-5, it appears that the ROI in unsaturated soils (1-6 feet bgs) is at least 10 feet, and may be as much as 20 feet.

### **Soil Gas Chemistry Results**

Soil gas samples were collected for field screening and laboratory analysis at UST 702 in June 1997, 1 month after the blower was turned off (on May 13, 1997). Soil gas sampling results from this Option 1 testing event, as well as soil gas sampling results from the initial March 1996 testing event, are presented in Table 15 (attached). During the June 1997 sampling event, the static soil gas oxygen concentration at MPB was below 6 percent, indicating that significant oxygen demand still exists in the soils near MPB, and that aerobic fuel biodegradation is still taking place at significant rates. The higher oxygen level at VW1 is the result of long-term air injection at this well; most of the fuel contamination initially present at this location has been aerobically biodegraded or has volatilized and migrated away from the injection point via soil gas advection. At all locations, field TVH levels in soil gas were low, ranging from 200 to 460 ppmv.

A soil gas sample collected at MPB-5 was submitted under chain-of-custody to the Air Toxics, Ltd. laboratory and analyzed for TVH and BTEX using USEPA Method TO-3. Laboratory soil gas TVH concentrations at MPB-5 have increased, likely due to redistribution of contaminants caused by the "smearing effect". Although laboratory TVH levels at MPB increased, the risk-driving BTEX compounds remained at low concentrations (Table 15).

### **Respiration Testing Results**

After the soil gas sampling was completed at UST 702, an *in situ* respiration test was performed according to procedures outlined in the AFCEE bioventing protocol document (Hinchee *et al.*, 1992). Air was injected for 22 hours into MPB-5 using a 1-cfm pump to locally oxygenate the soils. Following the air injection period, changes in soil gas oxygen, carbon dioxide, and TVH concentrations were monitored for 26 hours. Observed rates of oxygen utilization were then used to estimate aerobic fuel biodegradation rates. Table 16 (attached) presents the results of respiration testing performed at UST 702 in March 1996 and June 1997.

Oxygen utilization rates were still significant at MPB-5. The oxygen utilization rate at MPB-5 was 0.34 percent per hour, with an estimated TPH biodegradation rate of 600 mg/kg/yr. The oxygen consumption rate in June 1997 was significantly lower than it had been during initial testing, indicating that only moderate amounts of fuel hydrocarbons remain in soils. Soil moisture content was likely higher during the June 1997 testing, so the actual biodegradation rates at MPB-5 may have been slightly lower than reported estimates.

### **Natural Attenuation Monitoring**

During the June 1997 (Option 1) field event, Parsons ES collected groundwater samples from all four site monitoring wells (TW1601 through TW1604) and one background monitoring well (MW011) to evaluate the RNA of groundwater contaminated by heating oil. Table 17 (attached) summarizes historic site analytical

data for groundwater samples. In June 1997, groundwater samples were analyzed by Parsons ES personnel in the field for alkalinity, DO, ferrous iron, free carbon dioxide, pH, redox potential, nitrate, soluble manganese, sulfate, and temperature. The results of these analyses are provided in Table 18 (attached). Samples for BTEX analysis by USEPA Method SW8020 and PAHs by USEPA Method SW8310 were shipped via Federal Express to EAL in Wheat Ridge, Colorado, and results are summarized in Table 17 along with the historic results. Groundwater samples were collected and analyzed according to the protocol developed for the AFCEE Natural Attenuation Initiative (Wiedemeier *et al.*, 1995). Based on available groundwater analytical data, dissolved BTEX contamination is not believed to be present at the site; however, low concentrations of heavier fuel constituents may migrate approximately 30 feet downgradient from the former UST.

Considering the contaminant type (heating oil), it is not surprising that the groundwater contaminant concentrations at UST 702 already are below state groundwater MCLs for BTEX, and below ASTM (1995) RBCA guidance for BTEX, naphthalene, and benzo(a)pyrene. Geochemical data collected during June 1997 suggests that biodegradation of fuel hydrocarbons at UST 702 is occurring in the shallow aquifer via aerobic respiration and the anaerobic processes of iron reduction, sulfate reduction, denitrification, and manganese reduction (Table 18). The data indicates that the electron acceptors oxygen, nitrate, and sulfate are present at lower concentrations in the source area than background. Also, the metabolic byproducts ferrous iron and manganese are present at higher concentrations in the source area than background. Considering the type and limited extent of contamination at UST 702, groundwater LTM is not recommended.

### Recommendations

Based on the respiration testing results, and the 1-year soil sampling results from UST 702, site closure with no further remedial action is recommended. Upon AFCEE concurrence, Parsons ES will begin to develop a closure report for UST 702. As an initial step, ADPC&E will be contacted to determine if any additional information is needed to obtain closure, or if the site can be closed based on soil and groundwater analytical data already available.

Analytical results from the recent sampling event should provide sufficient evidence to support closure of UST 702. Most of the source area soils were removed during tank removal activities, leaving only a small area of vadose zone and saturated zone petroleum contamination near the vapor MPs. The remaining source area vadose zone soils have been remediated to below ASTM (1995) RBCA screening levels for BTEX, and dissolved BTEX was not detected in groundwater. The bioventing technology is applicable only to unsaturated soils. Therefore, considering the shallow depth to groundwater (6 feet bgs), and the limited extent of vadose zone petroleum contamination at UST 702, the soil treatment volume is minimal. Because soil BTEX concentrations at the site already are very low, continued system operation would provide only a slight risk-reduction benefit.

The risk posed by site-related contaminants through future ingestion of, or dermal contact with, groundwater by onsite receptors or downgradient, current or future receptors is considered to be minimal. Because site groundwater is migrating at a slow velocity, the potential for PAH-contaminated groundwater to reach a drinking water well or surface water feature is very low. Future lease or development of the area should contain use restrictions to prevent groundwater pumping, to protect existing groundwater wells to the extent possible, and to minimize contact with contaminated soils. Therefore, based on the positive results from confirmation soil and groundwater sampling at UST 702, the following recommendations are proposed pursuant to site closure:

- Continue bioventing system operation and land use controls until site closure is granted;
- Develop/regulate closure criteria with ADPC&E; and
- Dismantle bioventing system and properly abandon all site wells following site closure.

If you have any questions or require additional information, please contact us at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.



David Teets  
Site Manager



John Ratz, P.E.  
Project Manager

cc: Mr. Jerry Branum (Eaker AFB)  
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File 727876.68X10 Letter Results Report

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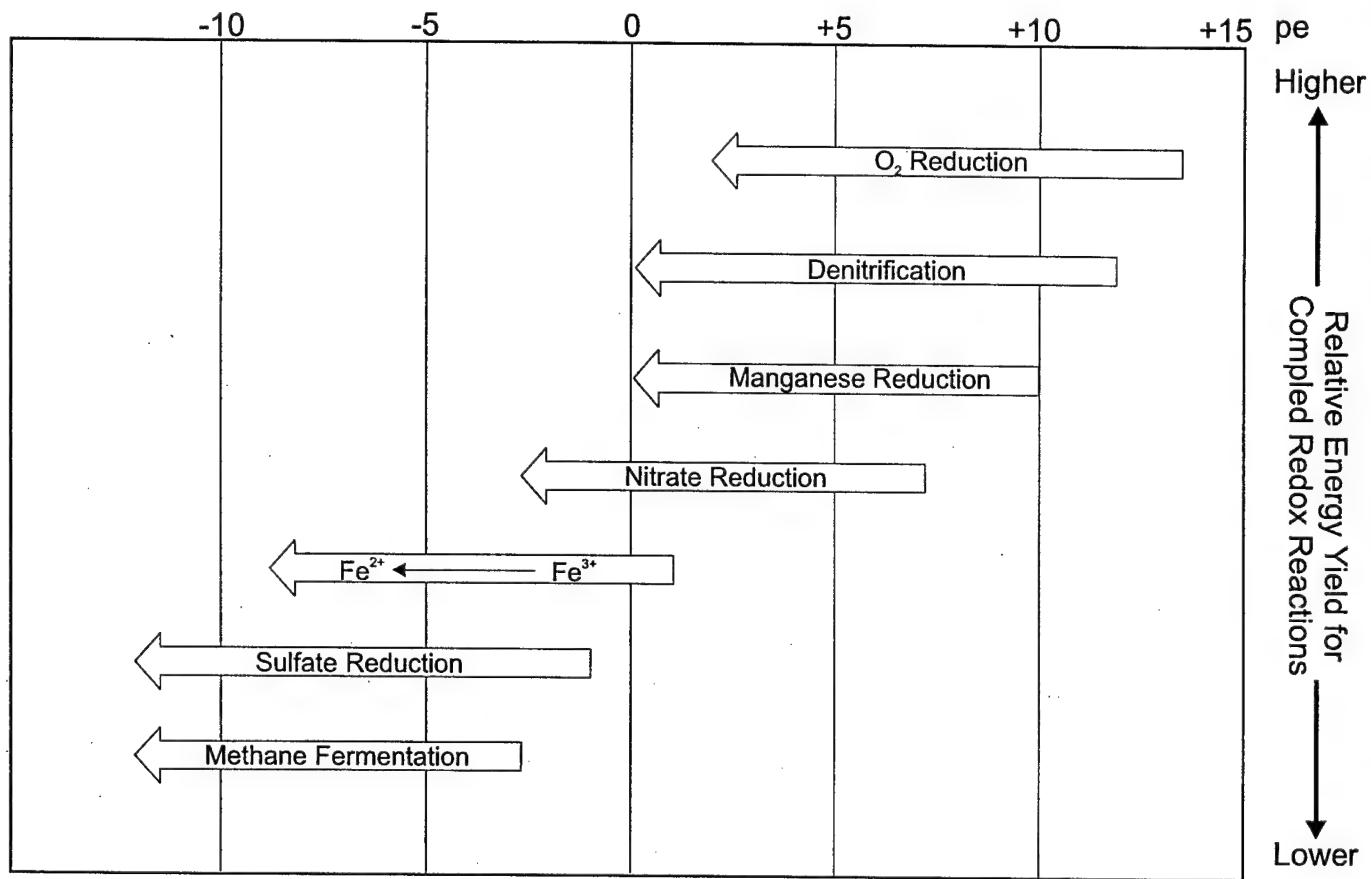
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## Notes

1. These reactions would be expected to occur in sequence if the system is moving toward equilibrium.
2. These redox processes occur in order of their energy-yielding potential (provided microorganisms are available to mediate a specific reaction). Reduction of a highly oxidized species decreases the pe of the system.
3. The pe of the system determines which electron acceptors are available for COC oxidation.
4. Redox sequence is paralleled by an ecological succession of biological mediators.

FIGURE 1

### SEQUENCE OF MICROBIALLY MEDIATED REDOX PROCESSES

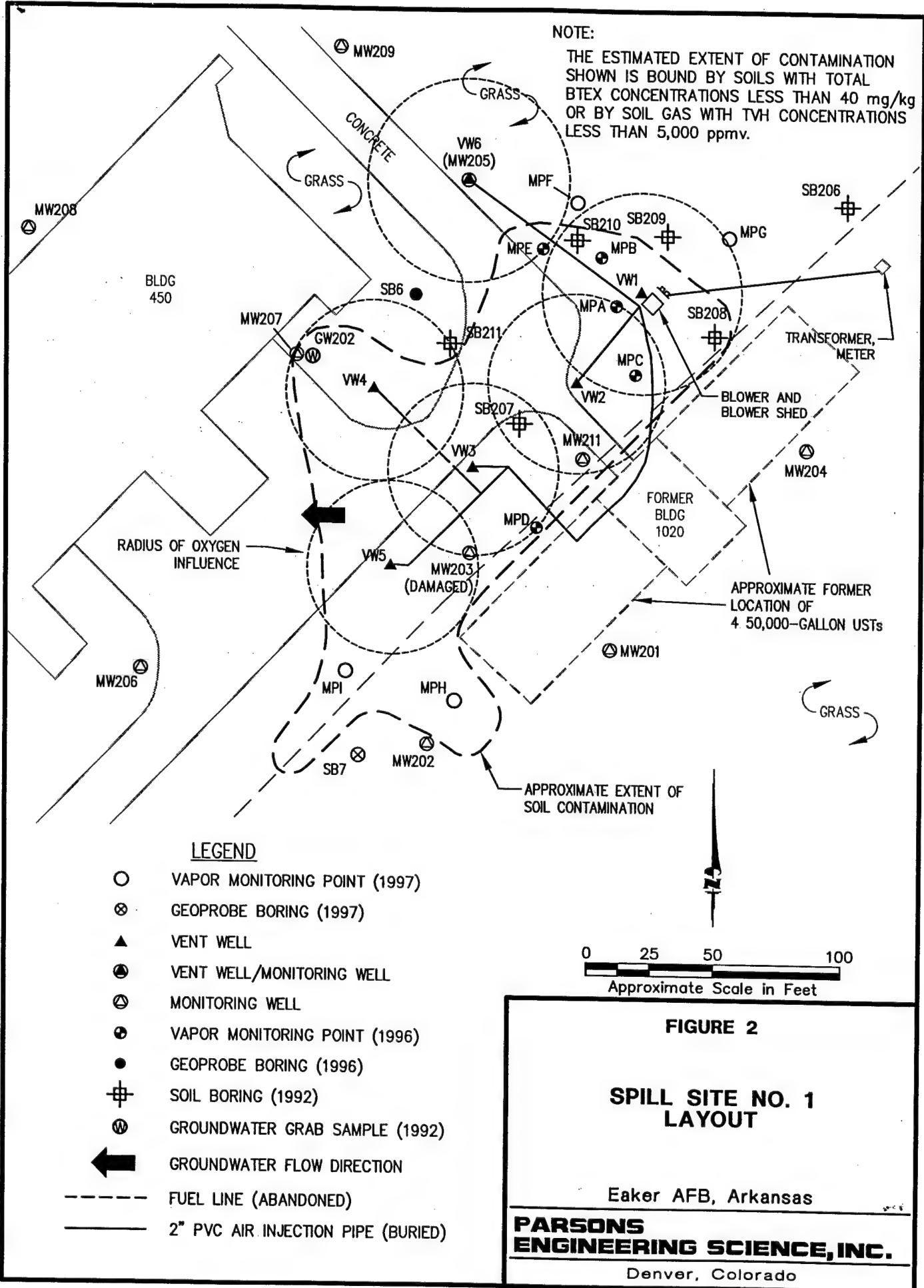
Eaker AFB, Arkansas

**PARSONS  
ENGINEERING SCIENCE, INC.**

Denver, Colorado

Adapted from Stumm and Morgan, 1981.

cdrl draw\726876A.cdr nap 9/15/97



**FIGURE 2**

## SPILL SITE NO. 1 LAYOUT

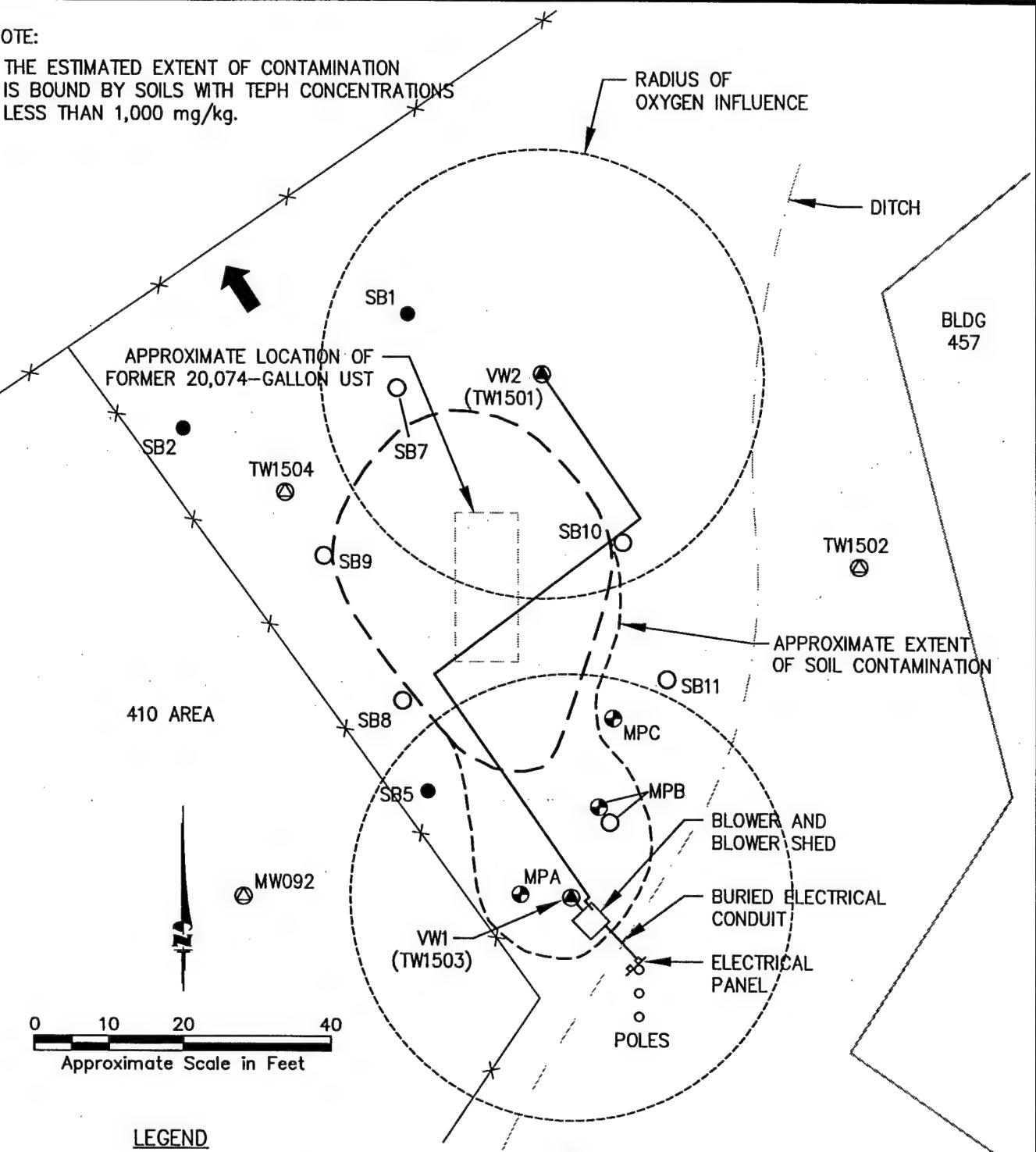
**Eaker AFB, Arkansas**

# **PARSONS ENGINEERING SCIENCE, INC.**

Denver, Colorado

NOTE:

THE ESTIMATED EXTENT OF CONTAMINATION  
IS BOUND BY SOILS WITH TEPH CONCENTRATIONS  
LESS THAN 1,000 mg/kg.



LEGEND

- VAPOR MONITORING POINT
- VENT WELL/MONITORING WELL
- MONITORING WELL
- GEOPROBE BORING (1996)
- GEOPROBE BORING (1997)
- 2" PVC AIR INJECTION PIPE (BURIED)
- APPROXIMATE LIMITS OF EXCAVATION
- GROUNDWATER FLOW DIRECTION

**FIGURE 3**

**BUILDING 457 AREA  
LAYOUT**

Eaker AFB, Arkansas

**PARSONS  
ENGINEERING SCIENCE, INC.**

Denver, Colorado

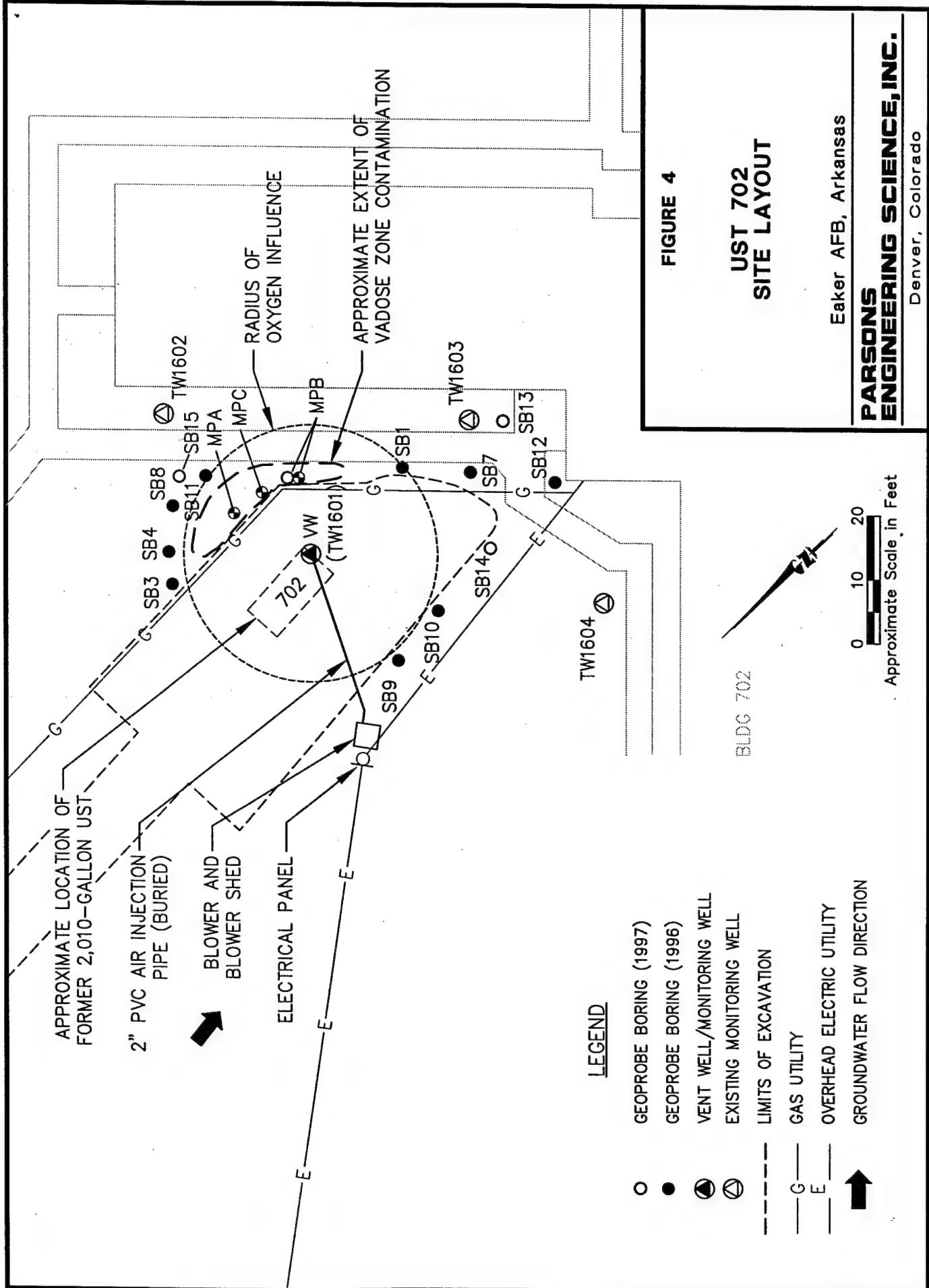


FIGURE 4

UST 702  
SITE LAYOUT

Eaker AFB, Arkansas

Denver, Colorado

**PARSONS  
ENGINEER**

Denver, Colorado

Denver, Colorado

A scale bar with markings at 0, 10, and 20, labeled "Approximate Scale in Feet".

K:\AFCCE\726876\97DNO702, 09/23/97 at 14:59

**TABLE 1**  
**SOIL LABORATORY ANALYTICAL RESULTS**  
**SPILL SITE NO. 1**  
**EAKER AFB, ARKANSAS**

Sampling Location	Sampling Depth (feet bgs) <sup>b/</sup>	Sampling Date	Laboratory Analytical Data				
			TVPH <sup>a/</sup> (mg/kg) <sup>c/</sup>	Benzene (µg/kg) <sup>d/</sup>	Toluene (µg/kg)	Ethylbenzene (µg/kg)	Xylenes (µg/kg)
<b>Bioventing Sampling Results</b>							
VW2	9-10	3/22/96	8,800	<560 <sup>e/</sup>	<560	54,000	160,000
VW4	10-10.5	3/22/96	280	<57	<57	810	2,000
VW5	9.5-10.5	3/22/96	4,400	<570	<570	19,000	30,000
MPB	9-9.5	3/20/96	620	<56	<56	1,800	7,600
MPB	9.5-10	3/20/96	3,200	<230	<230	12,000	41,000
MPC	10-11	3/20/96	11,000	<1,100	<1,100	85,000	180,000
MPD	9-10	3/20/96	7,800	<550	<550	50,000	46,000
MPF	7.5-8.5	6/15/97	----	<1.0	<2.0	<2.0	<2.0
MPG	5-6	6/15/97	----	<1.0	<2.0	<2.0	<2.0
MPI	8-9	6/15/97	----	<1.0	<2.0	36.2	49.1
SB7	6.5-8	6/15/97	----	8.1	4.4	44.8	32.4
<b>Select Site Investigation Results</b>							
MW201	8-9	4/28/88	ND <sup>f/</sup>	ND	ND	ND	ND
MW202	6-8	4/28/88	ND	ND	ND	ND	ND
MW203	7-8	4/29/88	575	ND	ND	3,200	12,100
MW204	NA <sup>h/</sup>	4/10/95	ND	ND	ND	ND	ND
MW205 (VW6)	9.7-10.2	4/9/95	ND	ND	ND	22	16
MW206	11.3-11.8	4/12/95	ND	ND	ND	ND	ND
MW207	9.5-10	4/10/95	ND	ND	ND	7.5	ND
SB206	7	5/20/92	ND	ND	ND	ND	ND
SB206	12.5	5/20/92	ND	ND	ND	ND	ND
SB207	6.5	5/21/92	ND	14	32	35	85
SB207	10-10.5	5/21/92	7,400	7,000 <sup>j/</sup>	ND	60,000	170,000
SB208	5.5	5/21/92	590	2,100 <sup>j</sup>	ND	13,000	50,000
SB208	9	5/21/92	9,500	3,200	ND	62,000	230,000
SB209	6	5/21/92	ND	ND	ND	ND	ND
SB209	9.5	5/21/92	ND	42 <sup>j</sup>	ND	ND	ND
SB209	13.5	5/21/92	ND	160	ND	ND	ND
SB210	6.0	5/21/92	ND	42 <sup>j</sup>	ND	ND	5
SB210	18.0	5/21/92	ND	7	ND	14	18
SB211	5.5	5/21/92	ND	ND	ND	ND	ND
SB211	10	5/21/92	50	ND	ND	1,800	5,900
GW202	15-18	5/9/92	---	690	ND	8,500	15,000

Note: March 1996 sampling was performed by Parsons ES (August 1996). 1988, 1992, and 1995 sampling was performed by Haliburton NUS.

<sup>a/</sup> TVPH = total volatile petroleum hydrocarbons by USEPA Method SW8015M.

<sup>b/</sup> bgs = below ground surface.

<sup>c/</sup> mg/kg = milligrams per kilogram.

<sup>d/</sup> µg/kg = micrograms per kilogram. Benzene, toluene, ethylbenzene, and xylene results by USEPA Method SW8020.

<sup>e/</sup> < = compound analyzed for, but not detected. Number shown represents the sample quantitation limit.

<sup>f/</sup> ---- = not analyzed.

<sup>g/</sup> ND = Compound not detected above the method detection limit (MDL).

<sup>h/</sup> NA = Not available.

<sup>j/</sup> J = compound detected above MDL and less than practical quantitation limit (PQL). Reported concentration is a laboratory estimate.

**TABLE 2**  
**INFLUENCE OF AIR INJECTION AT VWs ON**  
**MONITORING POINT OXYGEN CONCENTRATIONS**  
**SPILL SITE NO. 1**  
**EAKER AFB, ARKANSAS**

<b>Location</b>	<b>Distance From Nearest VW (feet)</b>	<b>Screen Depth (feet bgs)<sup>a/</sup></b>	<b>Initial O<sub>2</sub><sup>b/</sup> (%)</b>	<b>O<sub>2</sub> Influence<sup>c/</sup> (%)</b>
MPA	10.2 (from VW1)	9	1.4	19.8
MPB	20.2 (from VW1)	8.5	2.2	18.6
MPC	23.0 (from VW2)	5	20.5	15.8
MPC	23.0 (from VW2)	9	2.2	---
MPD	29.3 (from VW3)	5	---	0.0
MPD	29.3 (from VW3)	9	1.5	---
MPE	40.0 (from VW6)	9.5	1.3	19.2
MW201	88.0 (from VW3)	7-22	9.1 <sup>d/</sup>	8.2
MW203	32.0 (from VW5) 33.0 (from VW3)	6-21	4.2 <sup>e/</sup>	6.8
MW204	94.0 (from VW2)	N/A <sup>f/</sup>	19.8 <sup>e/</sup>	---
MW207	22.0 (from VW4)	11.6-21.6	0.0 <sup>d/</sup>	0.5
MW211	28.0 (from VW2)	9-19	18.9 <sup>e/g/</sup>	---

<sup>a/</sup> bgs = below ground surface.

<sup>b/</sup> Measurements taken on March 26, 1996, prior to 13 months of air injection.

<sup>c/</sup> Measurements taken on May 13, 1997, after approximately 13 months of air injection.

VW4 was found damaged during the June 1997 site visit.

<sup>d/</sup> --- = Not sampled because screened interval was submerged in perched groundwater.

<sup>e/</sup> Sample collected during the initial site visit on November 16, 1995. These wells were not sampled during 1996.

<sup>f/</sup> Screen depth information was not available for MW204.

<sup>g/</sup> Reported value is suspect, based on screen and groundwater depth and comparison to measurements collected from nearby monitoring points.

**TABLE 3**  
**SOIL GAS FIELD SCREENING AND LABORATORY ANALYTICAL RESULTS**  
**SPILL SITE NO. 1**  
**EAKER AFB, ARKANSAS**

Sampling Location	Screen Depth (feet bgs) <sup>d</sup>	Sampling Event <sup>d</sup>	Field Screening Data			Laboratory Analytical Data <sup>a/</sup>				
			Oxygen (percent)	Carbon Dioxide (percent)	TVH <sup>b/</sup> (ppmv) <sup>c/</sup>	TVH (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)
VW1	4-14	Initial 13-Month <sup>v</sup>	2.5	8.7	>20,000 <sup>f/</sup>	---	---	---	---	---
			---	---	---	---	---	---	---	---
VW2	4.5-14.5	Initial 13-Month	0.0	17.0	>20,000	60,000	670	190	120	120
			17.8	0.7	760	---	---	---	---	---
VW3	4.5-14.5	Initial 13-Month	0.0	19.0	>40,000	32,000	230	110	51	25
			17.5	2.1	220	---	---	---	---	---
VW4	5-20	Initial 13-Month	1.5	17.0	>40,000	22,000	100	130	58	71
			20.2	1.0	42	---	---	---	---	---
VW5	4.5-14.5	Initial 13-Month	20.8	0.4	260	---	---	---	---	---
			16.9	6.2	380	---	---	---	---	---
VW6 (MW205)	9.1-19.1	Initial 13-Month	3.2	19.0	>40,000	17,000	74	160	51	44
			2.5	10.2	370	---	---	---	---	---
MPA	9	Initial 13-Month	1.4	15.0	>20,000	5,900	43	48	24	50
			3.4	1.0	14,400	2,000	<0.22 <sup>v</sup>	0.95	1	11
MPB	5	Initial 13-Month	20.4	0.1	2,000	---	---	---	---	---
			0.9	5.0	6,800	---	---	---	---	---
MPB	8.5	Initial 13-Month	0.8	15.2	>20,000	6.6 <sup>j/</sup>	0.024 <sup>j/</sup>	0.07 <sup>j/</sup>	0.031 <sup>j/</sup>	0.27 <sup>j/</sup> M <sup>w</sup>
			1.2	5.0	6,400	5,700	1.2	17	7.4	41
MPC	5	Initial 13-Month	20.5	0.7	4,200	---	---	---	---	---
			14.2	6.0	26,000	12,000	12	19	20	140
MPC	9	Initial 13-Month	2.2	12.1	>20,000	16,000	110	87	51	50
			Purged water			---	---	---	---	---
MPD	5	Initial 13-Month	Purged water			---	---	---	---	---
			2.8	15.8	>40,000	---	---	---	---	---
MPD	9	Initial 13-Month	1.5	14.2	>20,000	20,000	63	92	39	11
			3.0	5.0	10,000	7,400	22	12	13	16
MPE	9.5	Initial 13-Month	1.3	15.2	>40,000	1,600 <sup>j/</sup>	34 <sup>j/</sup>	140 <sup>j/</sup>	39 <sup>j/</sup>	42 <sup>j/</sup>
			2.0	5.2	6,000	44,500 <sup>v</sup>	59 <sup>v</sup>	130 <sup>v</sup>	45.5 <sup>v</sup>	225 <sup>v</sup>
MPF	8.5	13-Month	0.0	5.0	1,600	1,400	4.6	4.9	0.35	1.2
MPG	6	13-Month	0.0	4.8	200	---	---	---	---	---
MPH	8	13-Month	0.0	9.0	>40,000	68,000	200	91	34	110
MPI	8	13-Month	0.2	10.8	>40,000	54,000	150	77	31	140 M

**TABLE 3 (Concluded)**  
**SOIL GAS FIELD SCREENING AND LABORATORY ANALYTICAL RESULTS**  
**SPILL SITE NO. 1**  
**EAKER AFB, ARKANSAS**

Sampling Location	Screen Depth (feet bgs) <sup>c</sup>	Sampling Event <sup>d</sup>	Field Screening Data			Laboratory Analytical Data <sup>e</sup>				
			Oxygen (percent)	Carbon Dioxide (percent)	TVH <sup>b</sup> (ppmv) <sup>f</sup>	TVH (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)
MW201	7-22	Initial	9.1	8.0	1,000	---	---	---	---	---
		13-Month	8.7	7.0	94	---	---	---	---	---
MW202	6.6-21.6	Initial	8.5	4.3	4,800	---	---	---	---	---
		13-Month	Purged water			---	---	---	---	---
MW203	6-21 (Damaged)	Initial	4.2	11.2	> 10,000	---	---	---	---	---
		13-Month	1.0	15.0	> 40,000	---	---	---	---	---
MW204	NA	Initial	19.8	1.6	150	---	---	---	---	---
		13-Month	15.9	4.0	90	---	---	---	---	---
MW206		13-Month	20.8	0.05	0	---	---	---	---	---
MW207	11.5-21.5	Initial	0.0	12.0	6,000	---	---	---	---	---
		13-Month	0.4	10.9	4,800	---	---	---	---	---
MW211	9-19	Initial	18.9	2.3	> 10,000	---	---	---	---	---
		13-Month	Purged water			---	---	---	---	---

<sup>a</sup> Laboratory analysis of soil gas performed using USEPA Method TO-3. Laboratory TVH referenced to jet fuel (MW=156).

<sup>b</sup> TVH = total volatile hydrocarbons.

<sup>c</sup> bgs = below ground surface.

<sup>d</sup> Soil gas sampling performed in March 1996 (initial event) and June 1997 (13-month event).

<sup>e</sup> ppmv = parts per million, volume per volume.

<sup>f</sup> > = denotes field measurement greater than maximum meter reading.

<sup>g</sup> --- = not analyzed.

<sup>h</sup> 13-month soil gas samples were collected approximately 1 month following blower shut down.

The blower operated almost continuously from April 4, 1996 until May 13, 1997.

<sup>i</sup> < = compound analyzed for, but not detected. Number shown represents the sample quantitation limit.

<sup>j</sup> Laboratory result is suspect based on field soil gas measurements and/or soil analytical results.

<sup>k</sup> M = reported laboratory value may be biased due to apparent matrix interferences.

<sup>l</sup> Average of the primary and duplicate laboratory sample results.

TABLE 4  
RESPIRATION TEST RESULTS AND FUEL BIODEGRADATION RATES  
SPILL SITE NO. 1  
EAKER AFB, ARKANSAS

Sampling Location-Depth (feet below ground surface)	Initial (March 1996)			13-Month (June 1997)		
	O <sub>2</sub> Utilization Rate (K <sub>o</sub> ) (% O <sub>2</sub> /hour)	Biodegradation Rate (mg/kg/year) <sup>a</sup>	Soil Temperature (°F)	O <sub>2</sub> Utilization Rate (K <sub>o</sub> ) (% O <sub>2</sub> /hour)	Biodegradation Rate <sup>b</sup> (mg/kg/year)	Soil Temperature (°F)
VW2-4.5-14.5	0.97	1,300	NM <sup>c</sup>	NM	NC <sup>d</sup>	NM
MPA-9	1.08	1,740	NM	1.30	2,090	NM
MPB-9	1.10	1,775	NM	1.16	1,870	NM
MPC-9	1.25	2,010	NM	NM	NC	NM
MPD-9	1.11	1,790	NM	2.68 <sup>e</sup>	4,310 <sup>e</sup>	NM
MPG-6 <sup>f</sup>	NM	NC	NM	NM	NC	60.5

<sup>a</sup> Milligrams of petroleum hydrocarbons per kilogram of soil per year.

<sup>b</sup> Assumes soil moisture content is equal to March 1996 values. Actual moisture content likely was higher during the June 1997 testing.

<sup>c</sup> NM = not measured.

<sup>d</sup> NC = not calculated.

<sup>e</sup> The air injection period for the 13-month test was double that of the initial respiration test, thereby possibly affecting the oxygen utilization rate.

<sup>f</sup> MPG was installed on June 15, 1997.

TABLE 5  
GROUNDWATER LABORATORY ANALYTICAL DATA SUMMARY  
SPILL SITE NO. 1  
EAKER AFB, ARKANSAS

		Well Number													
Parameter (Units)	Date Sampled	GW202	GW201	MW202	MW203	MW204	MW205	MW206	MW207	MW208	MW209	MW2010	MW2011	MW2012	
Organics	5/9/92	6/15/95	6/9/83	7/17/91	12/1/91	6/15/95	6/15/95	6/15/95	6/16/95	6/19/97	6/16/95	6/26/95	6/25/95	6/18/97	
USEPA Method SW8015 (mg/L) <sup>w</sup>	13	< 0.4 <sup>x</sup>	5.9	ND <sup>y</sup>	0.7	< 0.4	—	< 0.4	—	—	< 0.4	—	< 0.4	< 0.4	—
USEPA Method SW8020 (µg/L) <sup>y</sup>															
Total Volatile Petroleum Hydrocarbons (TVPH)															
Volatile Aromatic Hydrocarbons															
Benzene	690	< 2	< 2	1,500	210	680	< 2	< 0.4	< 2	< 0.4	< 2	< 0.4	< 2	< 2	5.5
Toluene	ND	< 2	< 2	ND	ND	< 2	< 0.4	3.2	< 2	< 0.4	< 2	< 0.4	< 2	< 2	130
Chlorobenzene	—	—	—	—	—	—	< 0.4	—	—	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	—
Ethylbenzene	8,500	< 2	< 2	550	15	21	< 2	< 0.4	< 2	< 0.4	< 2	< 0.4	< 2	< 2	9.5
Total Xylenes	15,000	< 5	1,210	ND	13	ND	< 5	< 0.4	< 5	< 0.4	< 5	< 0.4	< 5	< 2	110
Total BTEX	24,190	< 11	3,260	225	714	< 11	1.6	12.2	< 11	1.6	< 11	1.6	< 11	< 11	58
1,3,5-TMB <sup>x</sup>	—	—	—	—	—	—	< 0.4	—	—	< 0.4	—	—	< 0.4	—	298
1,2,4-TMB	—	—	—	—	—	—	< 0.4	—	—	< 0.4	—	—	< 0.4	—	27
1,2,3-TMB	—	—	—	—	—	—	< 0.4	—	—	< 0.4	—	—	< 0.4	—	250
1,2,3,4-TMB <sup>x</sup>	—	—	—	—	—	—	< 0.4	—	—	< 0.4	—	—	< 0.4	—	31
MTBE <sup>x</sup>	—	—	—	—	—	—	< 0.5	—	—	< 0.5	—	—	< 0.5	—	2.4
USEPA Method SW8270 (µg/L)															
Semivolatile Aromatic Hydrocarbons															
Naphthalene	< 11	< 10	—	—	—	< 11	< 11	< 11	< 11	< 11	< 11	< 10	< 10	< 10	—
Benz(a)pyrene	< 11	< 10	—	—	—	< 11	< 11	< 11	< 11	< 11	< 11	< 10	< 10	< 10	—
Laboratory Geochemical Parameters															
USEPA Method 3541 (mg/L)															
Nitrogen, Nitrite	0.01	—	0.03	—	—	—	0.03	—	0.02	0.01	—	—	0.04	—	0.05
Nitrogen, Nitrate	1.52	—	0.09	—	—	—	7.76	—	0.08	< 0.01	—	—	0.03	—	0.02
USEPA Method 375.3 (mg/L)															
Sulfate	7	—	6	—	—	—	14	—	3	4	—	2	—	5	—
USEPA Method 310.1 (mg/L)															
Alkalinity	210	—	250	—	—	—	270	—	800	820	—	710	—	700	—

Notes: 1988, 1991, 1992, and 1995 sampling was performed by Haliburton NUS (HNTUS).

Monitoring well MW201 was sampled on 6/8/88, 7/17/91 and 12/14/91; however, no VOCs were detected. Monitoring well MW203 is damaged.

x Field duplicate sample.

y mg/L = milligrams per liter.

— = not analyzed.

z < = compound analyzed for, but not detected. Number shown represents the sample quantitation limit.

ND = not detected above the method detection limit.

w µg/L = micrograms per liter. Sample GW202 was analyzed for VOCs by USEPA Method SW8260.

x TMB = trimethylbenzene.

y MTBE = methyl tertiary-buryl ether.

TABLE 6  
GROUNDWATER GEOCHEMICAL DATA  
SPILL SITE NO. 1  
EAKER AFB, ARKANSAS

Sampling Location	Sampling Date	Temperature (°C) <sup>a</sup>	Conductivity (µS/cm) <sup>b</sup>	Dissolved Oxygen (mg/L) <sup>c</sup>	Total Alkalinity (mg/L)	Redox Potential (mV) <sup>d</sup>	Sulfate (mg/L)	Ferrous Iron (mg/L)	CO <sub>2</sub> (mg/L)	Mn <sup>2+</sup> (mg/L)	Methane (Lab) (mg/L)
MW204	6/19/97	19.5	725	5.67	300	5.98	272.0	79.62	0.13	5.10	11.75 ND <sup>e</sup> < 0.0012 <sup>f</sup>
MW211	6/18/97	19.0	1384	0.58	740	6.34	520.1	51.69	5.10	ND	160 ND 7.5
MW207	6/19/97	22.3	949	1.15	620	6.46	224.0	5.27	0.07	0.08	11.3 1.3 0.0074
MW207D <sup>g</sup>	6/19/97	22.3	949	1.15	620	6.47	224.0	4.82	0.08	0.08	11.0 1.2 0.0070
MW208	6/19/97	18.2	1218	0.97	720	6.76	94.7	7.90	5.10	0.05	11.0 2.8 NA <sup>h</sup>
MW206	6/20/97	17.9	1370	1.66	820	6.60	231.2	6.71	0.02	0.13	10.75 3.4 NA
MW010 <sup>i</sup>	6/19/97	16.6	528	1.54	300	6.68	270.0	21.77	0.10	0.32	12.5 0.9 NA
(Background)											

<sup>a</sup>/ °C = degrees Celsius.

<sup>b</sup>/ µS/cm = microsiemens per centimeter.

<sup>c</sup>/ mg/L = milligrams per liter.

<sup>d</sup>/ mV = millivolts.

<sup>e</sup>/ ND = Compound not detected above the method detection limit (MDL).  
<sup>f</sup>/ < = Compound analyzed for, but not detected. Number shown represents the sample quantitation limit.

<sup>g</sup>/ Duplicate sample.

<sup>h</sup>/ NA = Not analyzed.

<sup>i</sup>/ Background monitoring well MW010 is located approximately 1,200 feet southeast of Spill Site No. 1.

TABLE 7  
SOIL LABORATORY ANALYTICAL RESULTS  
BUILDING 457  
EAKER AFB, ARKANSAS

Parameter (Units)	Investigation Sampling Location	Tank Removal		Site Investigation				Initial Bioventing				1-Year Bioventing			
		Pit (N)	Pit (W)	Pit (E)	TW1501	TW1502	TW1503	TW1504	MPA	MPB	MPC	MPB	SB8	SB8	SB11
Sampling Depth	12'	12'	12'	2'-3'	9'-10'	6'-6.5'	5'-5.5'	5'-6.5'	5'-6'	6'-7'	5'-6'	11'-12.5'	12.5'-13.5'	10'-11'	11'-11.5'
Date Sampled	8/2/94	8/2/94	8/2/94	8/2/94	8/26/95	8/26/95	8/27/95	8/27/95	3/18/96	3/19/96	6/16/97	6/16/97	6/16/97	6/16/97	6/16/97
USEPA Method SW8015 (mg/kg) <sup>a</sup>	<3.2 <sup>a</sup>	<3.1	4,700	1,400	<3.9	4.8	<4.0	<4.0	1,900	5,000	290	4,720	..... <sup>d</sup>	.....	.....
USEPA Method SW8020 (0.8%kg) <sup>a</sup>															
Total Extractable Petroleum Hydrocarbons (TEPH) <sup>b</sup>															
Volatile Aromatic Hydrocarbons															
Benzene															
Toluene															
Ethylbenzene															
Total Xylenes (m,p,o)															
1,3,5-TMB <sup>c</sup>															
1,2,4-TMB															
1,2,3-TMB															
1,2,3,4-TEMB <sup>c</sup>															
USEPA Method SW8310 (0.8/kg)															
Polyaromatic Hydrocarbons															
Naphthalene															
Acenaphthylene															
Acenaphthene															
Fluorene															
Phenanthrene															
Anthracene															
Fluoranthene															
Pyrene															
Benz(a)anthracene															
Chrysene															
Benz(b)fluoranthene															
Benz(k)fluoranthene															
Benz(a)pyrene															
Dibenz(a,h)anthracene															
Benz(g,h,i)perylene															
Indeno(1,2,3- <i>o</i> )pyrene															

Note: March 1996 sampling was performed by Parsons ES (August 1996). August 1995 sampling was performed by HNUS. Tank removal sampling (1994) was performed by Ogden Environmental and Energy Service

<sup>a</sup> USEPA = United States Environmental Protection Agency, mg/kg = milligrams per kilogram.

<sup>b</sup> Tank Removal: TEPH corresponds to carbon chain C6-C32. Investigation: Carbon chain unknown. Bioventing: TEPH corresponds to carbon chain C11-C28.

<sup>c</sup> < = compound analyzed for, but not detected. Number shown represents the sample quantitation limit.

<sup>d</sup> ---- = not analyzed.

<sup>e</sup> 1kg/kg = micrograms per kilogram.

<sup>f</sup> TMB = trimethylbenzene.

<sup>g</sup> TEMB = tetramethylbenzene.

**TABLE 8**  
**INFLUENCE OF AIR INJECTION AT VWs ON**  
**MONITORING POINT OXYGEN CONCENTRATIONS**  
**BUILDING 457 AREA**  
**EAKER AFB, ARKANSAS**

<b>Location</b>	<b>Distance From VW1 (feet)</b>	<b>Screen Depth (feet bgs)<sup>a/</sup></b>	<b>Initial O<sub>2</sub><sup>b/</sup> (%)</b>	<b>O<sub>2</sub> Influence<sup>c/</sup> (%)</b>
MPA	5.5	5.5	5.1 <sup>d/</sup>	20.7
MPB	13.7	5	0.0	16.5
MPC	24.5	4.5	0.0	19.0

<sup>a/</sup> bgs = below ground surface.

<sup>b/</sup> Measurements taken on March 25, 1996, prior to the 13-month air injection period.

<sup>c/</sup> Measurements taken on May 13, 1997, after approximately 13 months of air injection.

<sup>d/</sup> Sample could not be collected prior to the respiration test because the screened interval was under perched groundwater. Therefore, soil gas chemistry after the respiration test and prior to air injection for the permeability test is presented. The initial oxygen concentration may have been slightly lower than the value shown; however, based on respiration data and sufficient time for soil gas stabilization, the reported oxygen concentrations may closely represent initial soil gas concentrations.

**TABLE 9**  
**SOIL GAS FIELD SCREENING AND LABORATORY ANALYTICAL RESULTS**  
**BUILDING 457 AREA**  
**EAKER AFB, ARKANSAS**

Sampling Location	Screen Depth (feet bgs) <sup>c</sup>	Sampling Event <sup>d</sup>	Field Screening Data			Laboratory Analytical Data <sup>e</sup>				
			Oxygen (percent)	Carbon Dioxide (percent)	TVH <sup>b</sup> (ppmv) <sup>f</sup>	TVH (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)
VW1 (TW1503)	5.5-15.5	Initial	5.0	8.0	540	48	0.016	0.17	0.048	0.80
		13-Month <sup>g</sup>	9.6	3.0	380	— <sup>h</sup>	—	—	—	—
VW2 (TW1501)	6-16	Initial	2.5	10.3	540	—	—	—	—	—
		13-Month	12.8	0.3	52	—	—	—	—	—
MPA	5.5	Initial <sup>h</sup>	5.1	1.6	230	—	—	—	—	—
		13-Month	4.2	7.0	240	300	<0.006 <sup>i</sup>	<0.006	0.007	0.062
MPB	5	Initial	0.0	8.0	3,200	380	0.34	2.7	1.5	0.93
		13-Month	1.3	17.7	3,200	820	0.23	1.3	0.85	4.9
MPC	4.5	Initial	0.0	8.1	920	81	0.013M <sup>j</sup>	0.024	0.084	0.28
		13-Month	0.8	15.8	200	140	<0.002	0.015	0.009	0.38
TW1502	8-18	Initial	9.5	7.3	94	—	—	—	—	—
		13-Month	Purged water			—	—	—	—	—
TW1504	5.5-15.5	Initial	7.9	5.9	140	—	—	—	—	—
		13-Month	9.1	6.2	70	—	—	—	—	—
MW092 (410 Area)	6-16	13-Month	0.9	13.0	20,000	—	—	—	—	—

<sup>a</sup> Laboratory analysis of soil gas performed using USEPA Method TO-3. Laboratory TVH referenced to jet fuel (MW=156).

<sup>b</sup> TVH = total volatile hydrocarbons.

<sup>c</sup> bgs = below ground surface.

<sup>d</sup> Soil gas sampling performed in March 1996 (initial event) and June 1997 (13-month event).

<sup>e</sup> ppmv = parts per million, volume per volume.

<sup>f</sup> 13-month soil gas samples were collected approximately 1 month following blower shut down.

The blower operated almost continuously from April 4, 1996 until May 13, 1997.

<sup>g</sup> — = not analyzed.

<sup>h</sup> Sample could not be collected prior to air injection for the respiration test because the screened interval was under perched groundwater. Therefore, soil gas chemistry after the respiration test and prior to the permeability test is presented. The initial oxygen concentration may have been slightly lower than the value shown; however, based on respiration data and sufficient time for soil gas stabilization, the reported oxygen concentrations may closely represent initial soil gas concentrations.

<sup>i</sup> < = compound analyzed for, but not detected. Number shown represents the sample quantitation limit.

<sup>j</sup> M = reported laboratory value may be biased due to apparent matrix interferences.

**TABLE 10**  
**RESPIRATION TEST RESULTS AND FUEL BIODEGRADATION RATES**  
**BUILDING 457 AREA**  
**EAKER AFB, ARKANSAS**

Sampling Location-Depth (feet below ground surface)	Initial (March 1996)		13-Month (June 1997)	
	O <sub>2</sub> Utilization Rate (K <sub>o</sub> ) (% O <sub>2</sub> /hour)	Biodegradation Rate (mg/kg/year) <sup>a/</sup>	O <sub>2</sub> Utilization Rate (K <sub>o</sub> ) (% O <sub>2</sub> /hour)	Biodegradation Rate <sup>b/</sup> (mg/kg/year)
VW1-5.5-15.5	2.59	1,220	NM <sup>c/</sup>	NC <sup>d/</sup>
MPA-5.5	3.04	1,430	NM <sup>e/</sup>	NC
MPB-5	3.13	1,470	2.41	1,130
MPC-4.5	3.45	1,620	2.57	1,210

<sup>a/</sup> Milligrams of petroleum hydrocarbons per kilogram of soil per year.

<sup>b/</sup> Assumes soil moisture content is equal to March 1996 values.

<sup>c/</sup> NM = not measured.

<sup>d/</sup> NC = not calculated.

<sup>e/</sup> MPA screened interval was submerged in groundwater.

**TABLE 11**  
**GROUNDWATER ANALYTICAL DATA SUMMARY**  
**BUILDING 457**  
**EAKER AFB, ARKANSAS**

Parameter (Units)	Date Sampled	Well number		
		TW1503	TW1502	TW1504
USEPA Method SW8015 (mg/L) <sup>a/</sup>				
Total Extractable Petroleum Hydrocarbons (TEPH)	1.5	— <sup>b/</sup>	—	—
USEPA Method SW8020 (µg/L) <sup>c/</sup>				
Volatile Aromatic Hydrocarbons				
Benzene	—	< 0.4 <sup>d/</sup>	< 0.4	< 0.4
Toluene	—	< 0.4	< 0.4	< 0.4
Chlorobenzene	—	< 0.4	< 0.4	< 0.4
Ethylbenzene	—	< 0.4	< 0.4	< 0.4
Total Xylenes (m,p,o)	—	< 0.4	< 0.4	< 0.4
Total BTEX	—	< 1.6	< 1.6	< 1.6
1,3,5-TMB <sup>e/</sup>	—	< 0.4	< 0.4	< 0.4
1,2,4-TMB	—	< 0.4	< 0.4	< 0.4
1,2,3-TMB	—	< 0.4	< 0.4	< 0.4
1,2,3,4-TEMB <sup>f/</sup>	—	< 0.5	< 0.5	< 0.5
MTBE <sup>g/</sup>	—	< 1.6	< 1.6	< 1.6
USEPA Method SW8310 (µg/L)				
Polynuclear Aromatic Hydrocarbons				
Naphthalene	—	— <sup>h/</sup>	< 18	< 18
Acenaphthylene	—	—	< 23	< 23
Acenaphthene	—	—	< 18	< 18
Fluorene	—	—	< 2.1	< 2.1
Phenanthrene	—	—	< 6.4	< 6.4
Anthracene	—	—	< 6.6	< 6.6
Fluoranthene	—	—	< 2.1	< 2.1
Pyrene	—	—	0.32 J	0.32 J
Benzo(a)anthracene	—	—	< 0.056 * J, B	< 0.056 * J, B
Chrysene	—	—	< 1.5	< 1.5
Benzo(b)fluoranthene	—	—	< 0.18	< 0.18
Benzo(k)fluoranthene	—	—	< 0.17	< 0.17
Benzo(a)pyrene	—	—	< 0.23	< 0.23
Dibenzo(a,h)anthracene	—	—	< 0.30	< 0.30
Benzo(g,h,i)perylene	—	—	< 0.76	< 0.76
Indeno(1,2,3-cd)pyrene	—	—	< 0.43	< 0.43

Note: 1995 sampling was performed by Haliburton NUS (1996).

<sup>a/</sup> mg/L = milligrams per liter.

<sup>b/</sup> — = not analyzed.

<sup>c/</sup> µg/L = micrograms per liter.

<sup>d/</sup> < = compound analyzed for, but not detected. Number shown represents the sample quantitation limit.

<sup>e/</sup> TMB = trimethylbenzene.

<sup>f/</sup> TEMB = tetramethylbenzene.

<sup>g/</sup> MTBE = methyl tertiary-butyl ether.

<sup>h/</sup> Sample jar for well TW1502 was broken during shipment.

\* = matrix interferences

J = detected above the method detection limit (MDL) and less than the practical quantitation limit (PQL).

B = also found in blank

TABLE 12  
GROUNDWATER GEOCHEMICAL DATA  
BUILDING 457  
EAKER AFB, ARKANSAS

Sampling Location	Sampling Date	Temperature (°C) <sup>a</sup>	Conductivity (µS/cm) <sup>b</sup>	Dissolved Oxygen (mg/L) <sup>c</sup>	Total Alkalinity (mg/L)	Redox Potential (mV) <sup>d</sup>	Sulfate (mg/L)	Ferrous Iron (mg/L)	Nitrate (mg/L)	CO <sub>2</sub> (mg/L)	Mn <sup>2+</sup> (mg/L)
TW1502	6/19/97	17.6	535	1.37	280	6.44	260	38.57	0.20	ND <sup>e</sup>	11.2
TW1504	6/19/97	17.3	322	2.53	160	6.09	610	27.09	0.04	1.9	11.8
MW010 <sup>f</sup> (Background)	6/19/97	16.6	528	1.54	300	6.68	270	21.77	0.10	0.32	12.5
											0.9

<sup>a</sup> °C = degrees Celsius

<sup>b</sup> µS/cm = microsiemens per centimeter

<sup>c</sup> mg/L = milligrams per liter

<sup>d</sup> mV = millivolts.

<sup>e</sup> ND = not detected above the method detection limit (MDL).

<sup>f</sup> Background monitoring well MW010 is located approximately 1,000 feet southeast of Building 457.

TABLE 13  
SOIL LABORATORY ANALYTICAL RESULTS  
UST 702  
EAKER AFB, ARKANSAS

Parameter (Units)	Investigation		Tank Removal		Site Investigation				Initial Bioventing				1-Year Bioventing				
	Sampling Location	Pit (N)	Pit (W)	Pit (E)	TW1/601	TW1/602	TW1/603	TW1/605	SB1/601	SB1/601	MPB	MPB	MPB	MPB	SB13	SB14	SB15
Sampling Depth	17'	17'	17'	3'-3.5'	4.5'-5'	5.5'-6'	11'-11.5'	5.5'-6.5'	11.5'-12'	6.5'-7'	5.5'-6'	5.5'-6'	18'-20'	18'-19.5'	17'-18.5'	17'-18.5'	
Date Sampled	7/8/94	7/5/94	7/5/94	9/12/95	9/12/95	9/12/95	9/12/95	9/14/95	9/14/95	3/21/96	3/21/96	6/17/97	6/17/97	6/20/97	6/20/97	6/20/97	
US EPA Method SW8015 (mg/kg) <sup>a</sup>	<3.3	<3.3	<3.3	12,000	6,100	<3.8	<4.1	<4.2	<4.7	<4.8	640	4,200	370	1,890	— <sup>d</sup>	—	—
Total Extractable Petroleum Hydrocarbons (TEPH) <sup>b</sup>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
US EPA Method SW8020 (µg/kg) <sup>c</sup>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Volatile Aromatic Hydrocarbons	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Benzene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Toluene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chlorobenzene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ethylbenzene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Xylenes (m.p.o)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,3,5-TMB <sup>e</sup>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2,4-TMB	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2,3-TMB	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,2,3,4-TEMB <sup>f</sup>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
US EPA Method SW8310 (µg/kg)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Polyaromatic Hydrocarbons	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Naphthalene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acenaphthylene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acenaphthene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fluorene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Phenanthrene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Anthracene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fluoranthene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pyrene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Benzo(a)anthracene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chrysene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Benzo(b)fluoranthene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Benzo(k)fluoranthene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Benzo(e)pyrene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dibenz(a,h)anthracene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Benzo(g,h,i)perylene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Indeno(1,2,3- <i>cd</i> )perylene	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note: March 1996 sampling was performed by Parsons ES (August 1996). September 1995 sampling was performed by HNUS (1996). Tank removal sampling (1994) was performed by Ogen Environmental and Energy Service.

\* USEPA = United States Environmental Protection Agency. mg/kg = milligrams per kilogram.

† Tank Removal: TEPH corresponds to carbon chain C6-C32. Investigation: Carbon chain unknown. Bioventing: TEPH corresponds to carbon chain C11-C28.

‡ < = compound analyzed for, but not detected. Number shown represents the sample quantitation limit.

§ — = not analyzed.

¶ µg/kg = micrograms per kilogram.

\*\* TMB = trimethylbenzene.

\*\*\* TEMB = tetramethylbenzene.

**TABLE 14**  
**INFLUENCE OF AIR INJECTION AT VW ON**  
**MONITORING POINT OXYGEN CONCENTRATIONS**  
**UST 702**  
**EAKER AFB, ARKANSAS**

Location	Distance From VW (feet)	Screen Depth (feet bgs) <sup>a/</sup>	Initial O <sub>2</sub> <sup>b/</sup> (%)	O <sub>2</sub> Influence <sup>c/</sup> (%)
MPB	10.4	5	5.5	17.0

<sup>a/</sup> bgs = below ground surface.

<sup>b/</sup> Measurement taken on April 1, 1996, prior to 13 months of air injection.

<sup>c/</sup> Measurement taken on May 12, 1997, after approximately 13 months of air injection.

**TABLE 15**  
**SOIL GAS FIELD SCREENING AND LABORATORY ANALYTICAL RESULTS**  
**UST 702**  
**EAKER AFB, ARKANSAS**

Sampling Location	Screen Depth (feet bgs) <sup>d</sup>	Sampling Event <sup>d</sup>	Field Screening Data			Laboratory Analytical Data <sup>v</sup>				
			Oxygen (percent)	Carbon Dioxide (percent)	TVH <sup>b/</sup> (ppmv) <sup>e/</sup>	TVH (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)
VW1 (TW1601)	6-16	Initial <sup>g/</sup>	1.1	11.0	540	---	---	---	---	---
		13-Month <sup>h/</sup>	9.6	3.0	380	---	---	---	---	---
MPA	5.5	Initial	20.8	0.05	30	---	---	---	---	---
		13-Month	---	---	---	---	---	---	---	---
MPB	5	Initial	5.5	12.2	510	48	0.020	0.12	0.12	22
		13-Month	5.2	7.8	460	120	0.024	0.072	0.061	0.42
MPC	4.5	Initial	20.8	0.05	18	---	---	---	---	---
		13-Month	20.7	0.6	200	---	---	---	---	---
TW1602	6-16	Initial	20.8	0.08	10	---	---	---	---	---
		13-Month	---	---	---	---	---	---	---	---
TW1603	6-16	Initial	20.8	0.08	13	---	---	---	---	---
		13-Month	---	---	---	---	---	---	---	---
TW1604	6-16	Initial	20.8	0.08	10	---	---	---	---	---
		13-Month	---	---	---	---	---	---	---	---

<sup>v</sup> Laboratory analysis of soil gas performed using USEPA Method TO-3. Laboratory TVH referenced to jet fuel (MW=156).

<sup>b/</sup> TVH = total volatile hydrocarbons.

<sup>d</sup> bgs = below ground surface.

<sup>e/</sup> Soil gas sampling performed in March 1996 (initial event) and June 1997 (13-month event).

<sup>g/</sup> ppmv = parts per million, volume per volume.

<sup>h/</sup> The screened interval was below groundwater; therefore, the soil gas chemistry observed during the November 16, 1995 site visit is presented.

<sup>---</sup> = not analyzed.

<sup>w/</sup> 13-month soil gas samples were collected approximately 1 month following blower shut down.

The blower operated almost continuously from April 4, 1996 until May 13, 1997

**TABLE 16**  
**RESPIRATION TEST RESULTS AND FUEL BIODEGRADATION RATES**  
**UST 702**  
**EAKER AFB, ARKANSAS**

Sampling Location-Depth (feet below ground surface)	Initial (March 1996)		13-Month (June 1997)	
	O <sub>2</sub> Utilization Rate (K <sub>o</sub> ) (% O <sub>2</sub> /hour)	Biodegradation Rate (mg/kg/year) <sup>a/</sup>	O <sub>2</sub> Utilization Rate (K <sub>o</sub> ) (% O <sub>2</sub> /hour)	Biodegradation Rate <sup>b/</sup> (mg/kg/year)
VW 6-16	0.67	1,160	NM <sup>c/</sup>	NC <sup>d/</sup>
MPB-5	0.57	990	0.34	600

<sup>a/</sup> Milligrams of petroleum hydrocarbons per kilogram of soil per year.

<sup>b/</sup> Assumes soil moisture content is equal to March 1996 values.

<sup>c/</sup> NM = not measured. VW screened interval was submerged in groundwater.

<sup>d/</sup> NC = not calculated.

**TABLE 17**  
**GROUNDWATER ANALYTICAL DATA SUMMARY**  
**UST 702**  
**EAKER AFB, ARKANSAS**

Parameter (Units)	Date Sampled	Well Number					
		TW1603	TW1601	TW1601D <sup>w</sup>	TW1602	TW1603	TW1604
USEPA Method SW8015 (mg/L) <sup>b</sup>							
Total Extractable Petroleum Hydrocarbons (TEPH)	<0.4 <sup>c</sup>	---	---	---	---	---	---
USEPA Method SW8020 (µg/L) <sup>e</sup>							
Volatile Aromatic Hydrocarbons							
Benzene	---	< 0.4	---	< 0.4	< 0.4	< 0.4	< 0.4
Toluene	---	< 0.4	---	< 0.4	< 0.4	< 0.4	< 0.4
Chlorobenzene	---	< 0.4	---	< 0.4	< 0.4	< 0.4	< 0.4
Ethylbenzene	---	< 0.4	---	< 0.4	< 0.4	< 0.4	< 0.4
Total Xylenes	---	< 0.4	---	< 0.4	< 0.4	< 0.4	< 0.4
Total BTEX	---	< 1.6	---	< 1.6	< 1.6	< 1.6	< 1.6
1,3,5-TMB <sup>v</sup>	---	< 0.4	---	< 0.4	< 0.4	< 0.4	< 0.4
1,2,4-TMB	---	< 0.4	---	< 0.4	< 0.4	< 0.4	< 0.4
1,2,3-TMB	---	< 0.4	---	< 0.4	< 0.4	< 0.4	< 0.4
1,2,3,4-TEMB <sup>v</sup>	---	< 0.5	---	< 0.5	< 0.5	< 0.5	< 0.5
MTBE <sup>w</sup>	---	< 1.6	---	< 1.6	< 1.6	< 1.6	< 1.6
USEPA Method SW8310 (µg/L)							
Polynuclear Aromatic Hydrocarbons							
Naphthalene	---	< 18	< 18	---	1.8 J	---	
Acenaphthylene	---	< 23	< 23	---	2.9 J	---	
Acenaphthene	---	< 18	< 18	---	< 18	---	
Fluorene	---	< 2.1	0.48 J	---	0.4 J	---	
Phenanthrene	---	< 6.4	1.9 J	---	4.1 J	---	
Anthracene	---	< 6.6	< 6.6	---	< 6.6	---	
Fluoranthene	---	< 2.1	< 2.1	---	< 2.1	---	
Pyrene	---	< 2.7	0.84 J	---	0.93 J	---	
Benzo(a)anthracene	---	< 0.13	0.14 B	---	0.18 J	---	
Chrysene	---	< 1.5	0.69 J	---	< 1.5	---	
Benzo(b)fluoranthene	---	< 0.18	0.12 J	---	0.16 J	---	
Benzo(k)fluoranthene	---	< 0.17	0.046 J	---	0.056 J	---	
Benzo(a)pyrene	---	< 0.23	0.091 J	---	0.10 J	---	
Dibenzo(a,h)anthracene	---	< 0.30	0.039 J	---	< 0.30	---	
Benzo(g,h,i)perylene	---	< 0.76	0.12 J	---	0.16 J	---	
Indeno(1,2,3-cd)pyrene	---	< 0.43	< 0.43	---	< 0.43	---	

Note: 1995 sampling was performed by Haliburton NUS (1996).

<sup>w</sup> Field duplicate sample.

<sup>b</sup> mg/L = milligrams per liter.

<sup>c</sup> < = compound analyzed for, but not detected. Number shown represents the sample practical quantitation limit (PQL).

<sup>d</sup> --- = not analyzed.

<sup>e</sup> µg/L = micrograms per liter.

<sup>v</sup> TMB = trimethylbenzene.

<sup>v</sup> TEMB = tetramethylbenzene.

<sup>w</sup> MTBE = methyl tertiary-butyl ether.

J = compound detected above method detection limit (MDL) and less than PQL.

B = compound also found in blank.

TABLE 18  
GROUNDWATER GEOCHEMICAL DATA  
UST 702  
EAKER AFB, ARKANSAS

Sampling Location	Sampling Date	Temperature (°C) <sup>a</sup>	Conductivity (µS/cm) <sup>b</sup>	Dissolved Oxygen (mg/L) <sup>c</sup>	Total Alkalinity (mg/L)	pH	Redox Potential (mV) <sup>d</sup>	Sulfate (mg/L)	Ferrous Iron (mg/L)	Nitrate (mg/L)	CO <sub>2</sub> (mg/L)	Mn <sup>2+</sup> (mg/L)
TW1601	6/20/97	17.1	363	1.01	180	6.36	462.4	41.50	1.04	0.11	13.25	2.1
TW1601D <sup>e</sup>	6/20/97	17.1	363	1.01	200	6.36	462.4	42.40	1.05	0.07	12.75	2.0
TW1602	6/21/97	17.0	186	6.27	25	5.44	196.3	54.27 <sup>f</sup>	0.08 <sup>f</sup>	1.9 <sup>f</sup>	12.75	ND <sup>g</sup> <sup>h</sup>
TW1603	6/20/97	16.1	211	7.41	90	5.83	184.4	50.40 <sup>i</sup>	0.08 <sup>i</sup>	0.26 <sup>i</sup>	12.80	0.5 <sup>i</sup>
TW1604	6/20/97	17.7	141	8.05	45	5.75	150.3	34.34 <sup>i</sup>	0.06 <sup>i</sup>	0.9 <sup>i</sup>	13.90	ND <sup>i</sup>
MW011 <sup>h</sup> (Background)	6/20/97	16.3	113	2.50	80	5.13	195.0	36.58	0.01	0.31	12.5	0.1

<sup>a</sup> °C = degrees Celsius.

<sup>b</sup> µS/cm = microsiemens per centimeter.

<sup>c</sup> mg/L = milligrams per liter

<sup>d</sup> mV = millivolts.

<sup>e</sup> Duplicate sample.

<sup>f</sup> Sample was filtered (using a #30 glass filter) due to high total dissolved solids.

<sup>g</sup> ND = Compound not detected above the method detection limit (MDL).

<sup>h</sup> Background monitoring well MW011 is located approximately 900 feet south of Building 702.